Appendix 1

BIOLOGICAL RESOURCES SURVEY

for the

NORTH SHORE WIND POWER PROJECT

KAHUKU, KO'OLAULOA, HAWAI'I

by

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INTRODUCTION

The North Shore Wind Power Project is located on the northern tip of O'ahu on 506 acres of land at Kahuku, Ko'olauloa (TMK (1) 5-6-05:007). It is bounded on the east and south by pasture and agricultural lands along the Kamehameha Highway and bordering the town of Kahuku, on the north by undeveloped military reservation land and on the west by rough mountainous land. This survey was initiated to address environmental requirements of the planning process.

SITE DESCRIPTION

This property is situated on a plateau above the coastal plain. The bluffs on the seaward edge of the plateau which stand at about 120 – 150 feet above sea level are made up of lithified sand from ancient coastal dunes which are now eroded and sculpted by the wind. The plateau itself is made up of soils of the Paumalu, Lahaina and Kaena series which are deep silty clays and clays (Foote et al, 1972). Inland the land slopes upward into hills and gullies to a maximum elevation of 535 feet. The vegetation is mostly dense brush and trees with an abundance of grass in the understory. Rainfall averages 45-50 inches per year with the bulk falling during the winter and spring months (Armstrong, 1983).

BIOLOGICAL HISTORY

The original native vegetation would have been a combination of coastal and lowland windward forests of dense character. Dominating this vegetation would have been such species as 'a'ali'i (*Dodonaea viscosa*), 'ohi'a (*Metrosideros polymorpha*), u'ulei (*Osteomeles anthyllidifolia*), hala (*Pandanus tectorius*) and a great variety of other trees, shrubs, vines and ferns.

During several hundred years of Hawaiian occupation, much of the more fertile lands would have been utilized for agriculture with a variety of food and fiber crops. Most of the surrounding areas, however, would have remained essentially native in character all the way to the shoreline.

Late in the 1800's this area was farmed for sugar production and this use continued for about 100 years. During this period the land was repeatedly plowed, planted, irrigated and harvested. Native plant species were all but eliminated from the area. Since the demise of sugar this area has been used for cattle grazing up until the present. The land is low largely covered with dense brush and trees with grasses and herbaceous weeds in the openings. Only a handful of hardy native plant species persist.

SURVEY OBJECTIVES

This report summarizes the findings of a flora and fauna inventory and assessment of the North Shore Wind Power Project area which was conducted in March 2007. The objectives of the survey were to:

1. Document what plant species occur on the property.
2. Document the status and abundance of each species.
3. Determine the presence or likely occurrence of any native flora and fauna. particularly any that are Federally listed as Endangered or Threatened. If such occur, identify what features of the habitat may be essential for these species.
4. Determine if the project area contains any special habitats which if lost or altered might result in a significant negative impact on the flora and fauna in this part of the island.

FLORA SURVEY REPORT SURVEY METHODS

A walk-through botanical survey method was used following a series of routes to ensure maximum coverage of all parts of this large property. Areas most likely to harbor native or rare plants such as gullies or rocky outcrops were more intensively examined. Notes were made on plant species, distribution and abundance as well as terrain and substrate.

DESCRIPTION OF THE VEGETATION

About 80% of this large property is covered with dense brush and trees. Smaller areas are more open with grasses and herbaceous species. A total of 128 plant species were recorded during the survey. Of these, all 13 of the abundant and common species were non-native plants. These were: sourgrass (*Digitaria insularis*), koa haole (*Leucaena leucocephala*), pitted beardgrass (*Bothriochloa pertusa*), Chinese violet (*Asystasia gangetica*), Christmas berry (*Schinus terebinthifolius*), parasol leaf tree (*Macaranga tanarius*), kolomona (*Senna surratensis*), common beggarticks (*Bidens alba*), sourbush (*Pluchea carolinensis*), allspice (*Pimenta dioeca*), lantana (*Lantana camara*), Jamaica vervain (*Stachytarpheta jamaicensis*) and pea aubergine (*Solanum torvum*).

Two endemic native species were found on the property: ni'ani'au (*Nephrolepis exaltata* subsp. *hawaiiensis*) and 'akia (*Wikstroemia oahuensis*). And additional seven indigenous native species were found on the property as well: pala'ā (*Sphenomeris chinensis*), pi'i pi'i (*Chrysopogon aciculatus*), 'ala'alawainui (*Peperomia blanda* var. *floribunda*), u'ulei, 'ilie'e (*Plumbago zeylanica*), popolo (*Solanum americanum*) and 'uhaloa (*Waltheria indica*). Five Polynesian introductions were found: ki (*Cordyline fruticosa*), niu (*Cocos nucifera*), kukui (*Aleurites moluccana*), 'ihi'ai (*Oxalis corniculata*) and noni (*Morinda citrifolia*). The remaining 114 plant species were non-native pasture grasses, or ornamental or agricultural weeds.

DISCUSSION AND RECOMMENDATIONS

The vegetation on this large property is largely non-native in character. The long history of agriculture and grazing has left little of the original native plants here. A few native species, 'ili'e'e, popolo and 'uhaloa, grow on the coral outcrops on the lower side of the property. A few others, ni'ani'au, 'akia, pala'ā, pi'ipi'i, u'ulei and 'ala'alawainiu, grow on the exposed ridge tops near the top of the property. All of the native species are both widespread and common in Hawai'i due to their ability to withstand disturbance and cattle grazing.

No Threatened or Endangered plant species were found on this property, nor were any found that are candidates for such status. No special habitats or native plant assemblages of significance were found either that would warrant protection.

It is determined that the activities associated with the development of the proposed project would not result in significant negative impacts on the native vegetation in this part of O'ahu.

While not of any special importance it is suggested that some of the hardy native species that already occur on the property, such as the u'ulei, the 'akia and the 'ilie'e, might be considered for propagation and out planting to stabilize bank slopes along any constructed access roads within the project area.

PLANT SPECIES LIST

Following is a checklist of all those vascular plant species inventoried during the field studies. Plant families are arranged alphabetically within each of four groups: Ferns, Conifers, Monocots and Dicots. Taxonomy and nomenclature of the ferns are in accordance with Palmer (2003). The conifers are in accordance with Krussman (1985). The flowering plants (Monocots and Dicots) are in accordance with Wagner et al. (1999).

For each species, the following information is provided:

1. Scientific name with author citation
2. Common English or Hawaiian name.
3. Bio-geographical status. The following symbols are used:
   endemic = native only to the Hawaiian Islands; not naturally occurring anywhere else in the world.
   indigenous = native to the Hawaiian Islands and also to one or more other geographic area(s).
   polynesian = those plants brought to the islands by the Hawaiians during their migrations.
   non-native = all those plants brought to the islands intentionally or accidentally after western contact.
4. Abundance of each species within the project area:
   abundant = forming a major part of the vegetation within the project area.
   common = widely scattered throughout the area or locally abundant within a portion of it.
   uncommon = scattered sparsely throughout the area or occurring in a few small patches.
   rare = only a few isolated individuals within the project area.

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
FERNS			
LINDSAEACEAE (Lindsaea Family)			
Sphenomeris chinensis (L.) Maxon	pala'ā	indigenous	rare
NEPHROLEPIDACEAE (Sword Fern Family)			
Nephrolepis exaltata (L.) Schott subsp. hawaiiensis W.H.Wagner	ni'ani'au	endemic	rare
POLYPODIACEAE (Polypody Fern Family)			
Phymatosorus grossus (Langsd. & Fisch.) Brownlie	laua'e	non-native	rare
CONIFERS			
PINACEAE (Pine Family)			
Pinus caribaea Morelet	Caribbean pine	non-native	rare
MONOCOTS			
AGAVACEAE (Agave Family)			
Agave sisalana Perrine	sisal	non-native	rare
Cordyline fruticosa (L.) A. Chev.	ki	polynesian	rare
ARECACEAE (Palm Family)			
Cocos nucifera L.	niu	polynesian	rare
Phoenix x dactylifera	hybrid date palm	non-native	rare
CYPERACEAE (Sedge Family)			
Cyperus rotundus L.	nut-sedge	non-native	rare
POACEAE (Grass Family)			
Andropogon virginicus L.	broomsedge	non-native	rare
Brachiaria mutica (Forssk.) Stapf	California grass	non-native	rare
Chloris barbata (L.) Sw.	swollen fingergrass	non-native	rare
Chloris divaricata R.Br.	stargrass	non-native	uncommon
Chrysopogon aciculatus (Retz.) Trin.	pi'i pi'i	indigenous	uncommon

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Cynodon dactylon (L.) Pers.	Bermuda grass	non-native	uncommon
Dactyloctenium aegytium (L.) Willd.	beach wiregrass	non-native	rare
Digitaria ciliaris (Retz.) Koeler	Henry's crabgrass	non-native	uncommon
Digitaria insularis (L.) Mez ex Ekman	sourgrass	non-native	abundant
Eleusine indica (L.) Gaertn.	wiregrass	non-native	uncommon
Eragrostis amabilis (L.) Wight & Arnott	Japanese lovegrass	non-native	rare
Eragrostis pectinacea (Michx.) Nees	Carolina lovegrass	non-native	rare
Panicum maximum Jacq.	Guinea grass	non-native	uncommon
Paspalum conjugatum Bergius	Hilo grass	non-native	rare
Paspalum dilatatum Poir.	Dallis grass	non-native	uncommon
Paspalum fimbriatum Kunth	Panama paspalum	non-native	rare
DICOTS			
ACANTHACEAE (Acanthus Family)			
Asystasia gangetica (L.) T.Anderson	Chinese violet	non-native	common
AMARANTHACEAE (Amaranth Family)			
Achyranthes aspera L.	chirchita	non-native	uncommon
Alternanthera pungens Kunth	khaki weed	non-native	rare
Amaranthus spinosus L.	spiny amaranth	non-native	uncommon
Amaranthus viridis L.	slender amaranth	non-native	rare
ANACARDIACEAE (Mango Family)			
Magnifera indica L.	mango	non-native	rare
Schinus terebinthifolius Raddi	Christmas berry	non-native	common
APIACEAE (Parsley Family)			
Centella asiatica (L.) Urb.	Asiatic pennywort	non-native	rare
Ciclospermum leptophyllum (Pers.) Sprague	fir-leaved celery	non-native	rare
ASTERACEAE (Sunflower Family)			

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Acanthospermum australe (Loefl.) Kuntze	spiny bur	non-native	rare
Ageratum conyzoides L.	maile hohono	non-native	uncommon
Bidens alba (L.) DC	common beggarticks	non-native	common
Calyptocarpus vialis Less.	straggler daisy	non-native	uncommon
Conyza bonariensis (L.) Cronquist	hairy horseweed	non-native	rare
Crassocephalum crepidioides (Benth.)S.Moore	red flower ragleaf	non-native	rare
Cyanthillium cinereum (L.) H. Rob.	little ironweed	non-native	rare
Emilia fosbergii Nicolson	red pualele	non-native	rare
Pluchea carolinensis (Jacq.) G.Don	sourbush	non-native	common
Pluchea indica (L.) Less.	Indian fleabane	non-native	rare
Synedrella nodiflora (L.) Gaertn.	nodeweed	non-native	rare
Verbesina encelioides (Cav.) Benth.&Hook.	golden crown-beard	non-native	rare
Xanthium strumarium L.	cocklebur	non-native	uncommon
BIGNONIACEAE (Bignonia Family)			
Spathodea campanulata P.Beauv.	African tulip tree	non-native	rare
BORAGINACEAE (Borage Family)			
Heliotropium procumbens Mill.	clasping heliotrope	non-native	rare
BRASSICACEAE (Mustard Family)			
Lepidium virginicum L.	peppergrass	non-native	rare
CARICACEAE (Papaya Family)			
Carica papaya L.	papaya	non-native	rare
CASUARINACEAE (She-oak Family)			
Casuarina equisetifolia Stickm.	common ironwood	non-native	uncommon
CHENOPODIACEAE (Goosefoot Family)			

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Chenopodium murale L.	'aheahea	non-native	rare
CONVOLVULACEAE (Morning Glory Family)			
Ipomoea obscura (L.) Ker-Gawl.	---------------	non-native	rare
EUPHORBIACEAE (Spurge Family)			
Aleurites moluccana (L.) Willd.	kukui	polynesian	rare
Chamaesyce hirta (L.) Millsp.	hairy spurge	non-native	rare
Chamaesyce hypericifolia (L.) Millsp.	graceful spurge	non-native	rare
Chamaesyce prostrata (Aiton.) Small	prostrate spurge	non-native	rare
Macaranga tanarius (L.) Mull. Arg.	parasol leaf tree	non-native	common
Phyllanthus debilis Klein ex Willd.	niruri	non-native	uncommon
Ricinus communis L.	Castor bean	non-native	rare
FABACEAE (Pea Family)			
Acacia confusa Merr.	Formosa koa	non-native	rare
Acacia farnesiana (L.) Willd.	klu	non-native	uncommon
Chamaecrista nictitans (L.) Moench	partridge pea	non-native	uncommon
Crotalaria incana L.	fuzzy rattlepod	non-native	rare
Crotalaria pallida Aiton	smooth rattlepod	non-native	rare
Crotalaria retusa L.	rattleweed	non-native	rare
Desmanthus pernambucanus (L.) Thellung	slender mimosa	non-native	uncommon
Desmodium incanum DC.	ka'imi clover	non-native	uncommon
Desmodium triflorum (L.)	three-flowered beggarweed	non-native	rare
Erythrina variegata L.	tiger claw	non-native	rare
Indigofera hendecaphylla Jacq.	creeping indigo	non-native	rare
Leucaena leucocephala (Lam.) de Wit	koa haole	non-native	abundant
Macroptilium lathyroides (L.) Urb.	wild bean	non-native	rare
Medicago lupulina L.	black medick	non-native	rare

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Mimosa pudica L.	sensitive plant	non-native	uncommon
Neonotonia wightii (Wight&Arnott) Lackey	glycine	non-native	rare
Samanea saman (Jacq.) Merr.	monkeypod	non-native	rare
Senna occidentalis (L.) Link	coffee senna	non-native	uncommon
Senna surratensis (N.L.Burm.)H.Irwin&Barneby	kolomona	non-native	common
Stylosanthes fruticosa (Retz.) Alston	shrubby pencilflower	non-native	uncommon
LAMIACEAE (Mint Family)			
Leonotis nepetifolia (L.) R.Br.	lion's ear	non-native	uncommon
Ocimum gratissimum L.	wild basil	non-native	rare
MALVACEAE (Mallow Family)			
Abutilon grandifolium (Willd.) Sweet	hairy abutilon	non-native	rare
Malva parviflora L.	cheeseweed	non-native	rare
Malvastrum coromandelianum (L.) Garcke.	false mallow	non-native	uncommon
Sida ciliaris (L.) D.Don	fringed fan petals	non-native	uncommon
Sida rhombifolia L.	Cuban jute	non-native	uncommon
Sida spinosa L.	prickly sida	non-native	uncommon
MELASTOMATACEAE (Melastoma Family)			
Clidemia hirta (L.) D.Don	Koster's curse	non-native	rare
MORACEAE (Fig Family)			
Ficus macrophylla Desf. ex Pers.	Moreton Bay fig	non-native	rare
Ficus microcarpa L.fil.	Chinese banyan	non-native	rare
Ficus platypoda A.Cunn.ex Miq.	rock fig	non-native	uncommon
MYRSINACEAE (Myrsine Family)			
Ardisia elliptica Thunb.	shoebutton ardisia	non-native	rare
MYRTACEAE (Myrtle Family)			

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Pimenta diocia (L.) Merr.	allspice	non-native	common
Psidium cattleianum Sabine	strawberry guava	non-native	rare
Psidium guajava L.	guava	non-native	uncommon
Syzygium cumini (L.) Skeels	Java plum	non-native	uncommon
NYCTAGINACEAE (Four-o'clock Family)			
Bougainvillea spectabilis Willd.	bougainvillea	non-native	rare
OXALIDACEAE (Wood Sorrel Family)			
Oxalis corniculata L.	'ihi'ai	polynesian	uncommon
Oxalis debilis Kunth	pink wood sorrel	non-native	rare
PASSIFLORACEAE (Passion Flower Family)			
Passiflora edulis Sims	passion fruit	non-native	rare
Passiflora suberosa L.	corkystem passion flower	non-native	uncommon
PHYTOLACCACEAE (Pokeweed Family)			
Rivina humilis L.	coral berry	non-native	uncommon
PIPERACEAE (Pepper Family)			
Peperomia blanda Kunth *var floribunda* (Miq.) H.Huber	'ala'alawainui	indigenous	rare
PLANTAGINACEAE (Plantain Family)			
Plantago lanceolata L.	narrow-leaved plantain	non-native	uncommon
PLUMBAGINACEAE (Plumbago Family)			
Plumbago zeylanica L.	'ilie'e	indigenous	rare
POLYGALACEAE (Milkwort Family)			
Polygala paniculata L.	milkwort	non-native	rare
POLYGONACEAE (Buckwheat Family)			
Antigonon leptopus Hook & Arnott	Mexican creeper	non-native	rare
Rumex obtusifolius L.	bitter dock	non-native	rare
PRIMULACEAE (Primrose Family)			

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Anagallis arvensis L.	scarlet pimpernel	non-native	rare
ROSACEAE (Rose Family)			
Osteomeles anthyllidifolia (Sm.) Lindl.	u'ulei	indigenous	rare
RUBIACEAE (Coffee Family)			
Morinda citrifolia L.	noni	Polynesian	rare
Spermacoce assurgens Ruiz & Pav.	buttonweed	non-native	rare
RUTACEAE (Rue Family)			
Citrus aurantiifolia (Christm.) Swingle	lime	non-native	rare
SAPOTACEAE (Sapodilla Family)			
Chrysophyllum oliviforme L.	satin leaf	non-native	uncommon
SOLANACEAE (Nightshade Family)			
Capsicum frutescens L.	chili pepper	non-native	rare
Solanum americanum Mill.	popolo	indigineous	rare
Solanum torvum Sw.	pea aubergine	non-native	common
STERCULIACEAE (Cacao Family)			
Waltheria indica L.	'uhaloa	indigenous	uncommon
THYMELAEACEAE ('Akia Family)			
Wikstroemia oahuensis (A. Gray) Rock	'akia	endemic	uncommon
TILIACEAE (Linden Family)			
Triumfetta rhomboidea Jacq.	diamond burrbark	non-native	rare
Triumfetta semitriloba Jacq.	Sacramento bur	non-native	uncommon
VERBENACEAE (Verbena Family)			
Lantana camara L.	lantana	non-native	common
Stachytarpheta cayennensis (Rich.) Vahl	nettle-leaved vervain	non-native	uncommon
Stachytarpheta jamaicensis (L.) Vahl	Jamaican vervain	non-native	common
Verbena litoralis Kunth.	ha'u owi	non-native	rare

FAUNA SURVEY REPORT

SURVEY METHODS

A walk-through survey method was conducted covering all parts of the project area. Field observations were made using binoculars and by listening to vocalizations. Notes were made on species abundance, activities and locations as well as observations of trails, tracks, scat and signs of feeding. In addition an evening visit was made to record crepuscular activities and vocalizations and to see if there was any evidence of the Endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) in the area.

MAMMALS

Three species of mammals were observed in the project area during three site visits. Taxonomy and nomenclature follow Tomich (1986).

Domestic cattle (*Bos taurus*) – Numerous cattle were being grazed on all parts of the property as part of a ranching operation.

Domestic horse (*Equus caballus*) – A few horses were also being grazed on the property by the ranch.

Feral pig (*Sus scrofa*) – One pig was seen in the dense brush and diggings and scat were widespread across the property.

Others mammals one might expect to be present, but which were not seen, include: mongoose (*Herpestes auropunctatus*), rats (*Rattus rattus)*, mice (*Mus domesticus*) and feral cats (*Felis catus*). Rats and mice feed on seeds, fruits and herbaceous vegetation, and the mongoose and cats hunt for these rodents as well as birds.

A special effort was made to look for the native Hawaiian hoary bat by making an evening survey in the most promising habitat on the property. The limestone bluffs on the lower edge of the property with their adjacent dense forests were reconnoitered during the evening hours for any activity. When present in an area these bats can be easily identified as they forage for insects, their distinctive flight patterns clearly visible in the glow of twilight. No evidence of such activity was observed though visibility was excellent and plenty of flying insects were seen.

Hawaiian hoary bats are extremely rare on O'ahu and no recent sightings have been made in this area.

BIRDS

Birdlife was moderate in both diversity and numbers considering the large size of the property and wide range of habitats. An ample supply of grass and herbaceous plant seeds as well as flying insects and caterpillars were present due to winter rains and spring growth. Sixteen species of birds were recorded during three site visits including fourteen non-native birds and two migratory visitors. Taxonomy and nomenclature follow American Ornithologists' Union (2005).

Zebra dove (*Geopelia striata*) – Small flocks of these doves were found on all parts of the property where they were seen feeding in grassy openings.

Common myna (*Acridotheres tristis*) – Many pairs of mynas were seen in trees or in flight overhead.

Red-vented bulbul (*Pycnonotus cafer*) – Many of these dark birds were seen in trees throughout the property and heard making their warbling calls.

Common waxbill (*Estrilda astrild*) – Several flocks of these tiny birds were seen feeding on grass seeds in forest openings or in flight.

Northern cardinal (*Cardinalis cardinalis*) – Many of these red birds were seen individually or in pairs and more were heard calling from forest trees.

House finch (*Carpodacus mexicanus*) – Small flocks were seen scattered across the property or congregating in ironwood trees.

White-rumped shama (*Copsychus malabaricus*) – Several of these shamas were heard making their prolonged melodic songs from dense forest patches.

Japanese white-eye (*Zosterops japonica*) – Several pairs of these small green birds were seen in forest trees and making their high-pitched calls.

Spotted dove (*Streptopelia chinensis*) – A few of these large doves were seen in flight moving between trees and forest openings.

Cattle egret (*Bubulcus ibis*) – A few of these large white egrets were seen flying over the property especially during the evening when they congregate to roost.

Nutmeg mannikin (*Lonchura punctulata*) – A few flocks of these small brown birds were seen in grassy openings and adjacent trees.

Chestnut manikin (*Lonchura Malacca*) – A few of these small reddish-brown birds were seen in grassy openings and adjacent shrubs.

Red-crested cardinal (*Paroaria coronata*) – Two pairs of these red-headed birds was seen and heard calling from forest trees.

African silverbill (*Lonchura cantans*) – One flock of these small pale silverbills was seen in a grassy opening in the lower part of the property.

Pacific golden-plover, Kolea (*Pluvialis fulva*) – Two of these migratory plovers were seen in an open pasture. They were growing out their breeding plumage in preparation for their flight to the arctic in April.

Ruddy turnstone, 'Akekeke (*Arenaria interpres*) – Two of these migratory turnstones were seen in an open pasture with the plovers. They too are preparing for their summer trip to the arctic breeding grounds.

Five species of native waterbirds, four of which are Endangered species: ae'o or black-necked stilt (Himantopus mexicanus knudseni), 'alae'ula or common moorhen (Gallinula chloropus sandvicensis), 'alae ke'oke'o or Hawaiian coot (Fulica alai) and koloa or Hawaiian duck (Anas wyvilliana) are known to frequent the extensive protected wetlands of the James Campbell National Wildlife Refuge about a mile away below Kamehameha Highway. These species, however, are all wetland obligates for feeding, breeding and nesting. They may periodically fly high over this subject property transiting between other wetland habitats, but there is no such habitat whatsoever that would attract these birds to land here or to utilize this property in any way. The subject property is also not suitable for Hawaii's native forest birds that require native forests at higher elevations.

INSECTS

While insects in general were not tallied, they were common throughout the area and fueled much of the bird activity observed. Although not found in the project site, one native Sphingid moth species, Blackburn's sphinx moth (Manduca blackburni), has been put on the federal Endangered species list and this designation requires special focus (USFWS, 2000). Blackburn's sphinx moth once occurred on Leeward O'ahu although it has not been seen in recent decades. Its native host plants are species of 'aiea (Nothocestrum) in the nightshade family. Some non-native alternative host plants, all also in the nightshade family, include commercial tobacco (Nicotiana tabacum), tree tobacco (Nicotiana glauca), tomato (Solanum lycopersicum) and eggplant (Solanum melongena). None of the above native or non-native host plants were found on the property and no Blackburn's sphinx moth or their larvae were seen.

DISCUSSION AND RECOMMENDATIONS

Fauna surveys are seldom comprehensive due to the short windows of observation, the seasonal nature of animal activities and the usually unpredictable nature of their daily movements. This survey would have recorded a few more non-native mammals and birds had the surveys extended longer and at different times of the year, but it is not likely that it would have found anything that was environmentally significant requiring special consideration.

None of the mammals, birds or insects found on the property are Threatened or Endangered species (USFWS,1999) nor are there any that are candidate for such status. The three mammal species and fourteen of the birds are common non-native species, that are of no environmental concern here in Hawaii. The two migrant birds, the kolea and ‘akekeke are seasonally widespread in both the Pacific and the arctic and carry no special federal status. No special fauna habitats were identified on the property either.

There is little of concern regarding the wildlife resources on the property. There is the remote possibility that Endangered waterfowl from the nearby wetlands could be struck by the turbine blades from the proposed windpower project, but as stated earlier there is nothing on the property that would attract these birds to their vicinity. Other than this highly unlikely occurrence, the project plans are not expected to have a significant negative impact on the fauna resources in this part of O'ahu.

COMMON NAME	SCIENTIFIC NAME	STATUS	ABUNDANCE
MAMMALS			
Cattle	*Bos taurus*	non-native	common
Horse	*Equus caballus*	non-native	uncommon
Pig	*Sus scrofa*	non-native	uncommon
BIRDS			
Zebra dove	*Geopelia striata*	non-native	common
Common myna	*Acridotheres tristis*	non-native	common
Red-vented bulbul	*Pycnonotus cafer*	non-native	common
Common waxbill	*Estrilda astrild*	non-native	common
Northern cardinal	*Cardinalis cardinalis*	non-native	common
House finch	*Carpodacus mexicanus*	non-native	uncommon
White-rumped shama	*Copsychus malabarica*	non-native	uncommon
Japanese white-eye	*Zosterops japonica*	non-native	uncommon
Spotted dove	*Streptopelia chinensis*	non-native	uncommon
Cattle egret	*Bubulcus ibis*	non-native	uncommon
Nutmeg mannikin	*Lonchura punctulata*	non-native	rare
Chestnut mannikin	*Lonchura malacca*	non-native	rare
Red-crested cardinal	*Paroaria coronata*	non-native	rare
African silverbill	*Lonchura cantans*	non-native	rare
Kolea, Pacific golden-plover	*Pluvialis fulva*	migratory	rare
'Akekeke, Ruddy turnstone	*Arenaria interpres*	migratory	rare

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Appendix 2

Firstwind Kahuku Wind Farm
Jurisdictional Wetland Determination Study

TMK 56005007
KAHUKU, O‘AHU, HAWAI‘I

Prepared for:

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October 2008

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

WETLAND DELINEATION SUMMARY

SITE NAME:	Firstwind Kahuku Wind Farm TMK 56005007
SITE LOCATION:	The site is located adjacent to the town of Kahuku on north shore of the Island of Oʻahu, within the state of Hawaiʻi.
OWNER:	Firstwind
DATE OF SITE VISITS:	June 4-5, 2008; June 16, 2008; October 6, 2008
PROJECT STAFF:	John Ford, Program Director / Senior Biologist, SWCA Dr. Ling Ong, Senior Scientist Dr. Shahin Ansari, Botanist Maya LeGrande, Botanist Stephen Mosher, Ornithologist Tiffany Thair, Environmental Specialist II, SWCA Ryan Taira, GIS Analyst, SWCA

SUMMARY

SWCA Environmental Consultants (SWCA) was tasked by Firstwind, the developer of the subject property, to identify wetlands subject to Department of the Army jurisdiction under Section 404 of the Clean Water Act. Wetland delineation fieldwork was conducted by SWCA on June 4-5, June 16, and October 6, 2008. SWCA's field studies were conducted utilizing methods prescribed in the US Army Corps of Engineers 1987 Wetlands Delineation Manual, as amended, in accordance with the requirements of US Army Corps of Engineers.

The US Fish and Wildlife Service (USFWS) conducted wetland mapping in Hawaiʻi based upon the Cowardin et al. (1979) wetland classification schema in 1981. According to the USFWS definition, three wetlands occur within the project parcel. Each of the following was described by USFWS as being palustrine, forested, broad-leafed evergreen, seasonal (PFO3C) wetlands: Ohiaʻai Gulch/Kiʻi Ditch, Kalaeokahipa Gulch, and an unnamed headwater tributary to James Campbell National Wildlife Refuge (NWR) (paralleling Nudist Camp Road). In addition, the lower reach of Ohiaʻai Gulch/Kiʻi Ditch, outside of the project boundary, is classified as palustrine, emergent, persistent, seasonally flooded, excavated (PEM1Cx).

No wetlands meeting the three established criteria of hydrophilic vegetation, soils, and water regime were found to occur within the project parcel during the survey by SWCA. However, SWCA determined that intermittent Ohiaʻai Gulch and Kalaeokahipa Gulch are likely to be subject to discretionary Department of the Army jurisdiction (in light of the *Rapanos* and *SWANCC* Supreme Court Decisions) because of their significance to the jurisdictional waters at the two units of the James Campbell National Wildlife Refuge (NWR), located immediately downstream of the project property.

1.0 INTRODUCTION TO WETLANDS AND WETLAND DELINEATION

The U.S. Army Corps of Engineers (Corps) derives its regulatory authority over wetlands and waters of the United States from the two Federal laws: Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act (33 CFR Part 328 and 329). Waters of the United States subject to Corps jurisdiction include navigable waters and their tributaries, interstate waters and their tributaries, wetlands adjacent to these waters, and impoundments of these waters. The U.S. Army Corps of Engineers, U.S. Environmental Protection Agency (EPA), and Hawai‘i Department of Health (HDOH) define wetlands as: *"Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swaps, marshes, bogs and similar areas"* (Erickson and Puttock 2006).

The Cowardin et al. (1979) definition of wetlands developed by the U.S. Fish and Wildlife Service is the standard for the agency and is the national standard for wetland mapping, monitoring and data reporting. As determined by the Federal Geographic Data Committee, wetlands are *"…are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year."*

Wetland jurisdictional boundary determinations involve an assessment of the relationship between indicators of vegetation, soil, and hydrologic regimes. Each is summarized below:

1.1 Vegetation Indicators

The U.S. Fish and Wildlife Service published a *National List of Vascular Plant Species That Occur in Wetlands*. The 1996 National Summary (draft revision) designates a regional wetland indicator status for plant species in Hawai‘i which estimates the probability of a species occurring in wetlands versus non-wetlands (USFWS 1997). Plants that are capable of living in anoxic conditions characteristic of inundated or saturated soils are considered hydrophytes if they are classified as OBL, FACW+, FACW, FACW-, FAC+, and FAC (Table 1). If more than 50 percent of the dominant vegetation at a site is hydrophytic, the entire area is considered to have wetland vegetation. The following factors are also listed as supplemental indicators of hydrophytic vegetation: visual observation of plant species growing in areas of prolonged inundation and/or soil saturation; morphological adaptations; technical literature; and physical and reproductive adaptations (Erickson and Puttock 2006).

Table 1. Wetland Plant Indicators published in the Corps' Wetlands Delineation Manual (1987).

PLANT INDICATOR	SYMBOL	DESCRIPTION
Obligate Wetland Species	OBL	>99% found in wetlands
Facultative Wetlands Species	FACW	67-99% found in wetlands
Facultative Species	FAC	33-66% found in wetlands
Facultative Upland Species	FACU	1-33% found in wetlands
Obligate Upland Species	UPL	<1% found in wetlands
No Indicator Status	NI	Ignored in count

(+) = wetter than FAC; (-) = drier than FAC; (*) = tentative assignment/more data needed

1.2 Soil Indicators

Hydric soils are defined as soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part (NRCS 2007). Hydric soils are either drained or undrained and are classified as either organic or mineral soils. Soil characteristic are determined in the field by digging 18 inch (45 cm) holes near potential wetland areas and documenting the texture, smell, color, and water level. For sandy soils, the following features are indicative of hydric soils: high organic content in the surface (A) horizon; streaking of subsurface horizons by organic matter; the presence of organic pans (Erickson and Puttock 2006).

The NRCS National List of Hydric Soils (February 2007) for O'ahu Island includes 13 hydric soils for the island. Soils within TMK 56005007 at Kahuku, O'ahu are mapped by the Natural Resources Conservation Service (Sato el al. 2001). No hydric soils are mapped by NRCS on the project parcel.

1.3 Hydrologic Indicators

Visual observation of inundation, visual observation of soil saturation, watermarks, drift lines, sediment deposition, and drainage patterns are all primary indicators of wetland hydrology. If a single primary indictor is present, the area can be considered to have wetland hydrology. The *Army Corps of Engineers Wetlands Delineation Manual* (1987, updated online version) states that "an area has wetland hydrology if it is inundated or saturated to the surface continually for at least 5% of the growing season." Erickson and Puttock (2006) note that because the growing season in Hawai'i is year-round, this equates to at least 18.5 consecutive days of inundation or saturation per year. Furthermore, regional indicators and secondary indicators can also be used to determine hydrological conditions. For example, the presence of tilapia redds (circular fish nests at the bottom of ponds or streams) is considered a regional indicator for wetland hydrology (Erickson and Puttock 2006).

2.0 REGIONAL BACKGROUND

2.1 Location and Vicinity

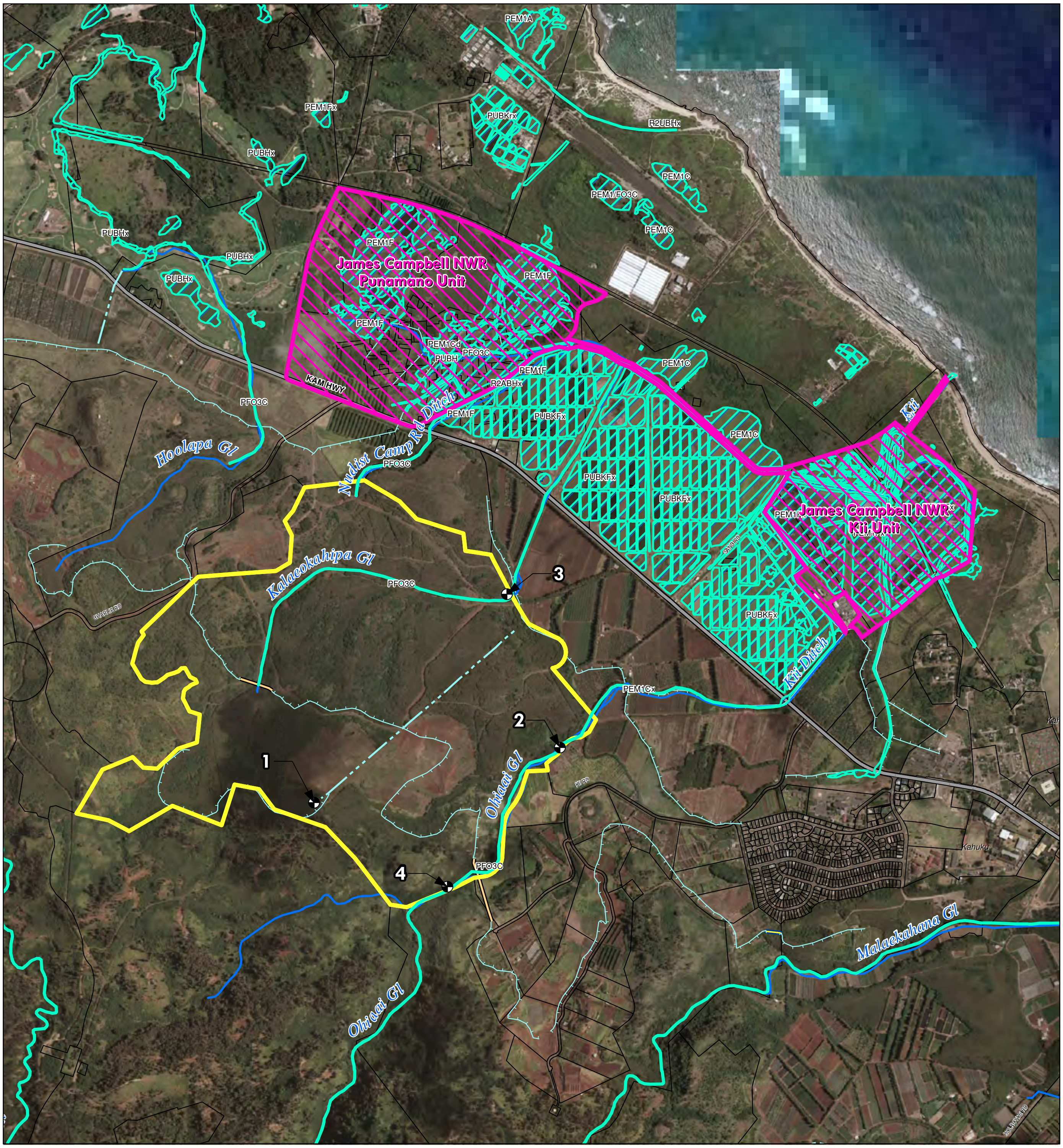
The wetland delineation was conducted in the community of Kahuku on the northeastern portion of the island of O'ahu, within the state of Hawai'i. The project area encompasses 506.85 acres (205.11 ha) and ranges from 120 to 535 feet (36.6-163 m) in elevation. The site is accessed by Charlie Road via Kamehameha Highway. It is bounded on the east and south by pasture and agricultural lands along the Kamehameha Highway, on the north by undeveloped military reservation land, and on the west by rough mountainous land (Hobdy 2007). Notable adjacent land uses include the Turtle Bay Resort, located about 0.5 mi (0.8 km) northwest of the site, and the Kuilima Wastewater Treatment Plant, located about 1 mi (1.6 km) northwest of the site. In addition, the James Campbell National Wildlife Refuge (NWR), which consists of two wetland units roughly two miles (3.2 km) apart: the Ki'i Unit (107.5 acres) and the Punamano Unit (37.5 acres), is located makai (seaward) of the property about a mile away below Kamehameha Highway (Figure 1).

The climate is characteristic of lowland areas on the windward side of O'ahu, with annual temperatures from 20.5 to 27.1°C (68.9-80.8°F) and annual precipitation between 37.88 and 40.86 inches (96.2 and 103.8 cm) (NOAA 2002, DBEDT 2007). Due to its location on the northern corner of O'ahu, Kahuku is considered a high wind energy site (Lau and Mink 2006). Prevailing northeasterly trade winds are present nearly 90 percent of the year in Kahuku and the southerly Kona winds are present approximately 10 percent of the year (Smith, Young & Assoc. 1990).

2.2 Geology and Soils

O'ahu, the third largest island in the Hawaiian archipelago, was created by several geological processes including shield-building volcanism, subsidence, weathering, erosion, sedimentation, and rejuvenated volcanism (Hunt 1996). The island is mostly composed of the heavily eroded remnants of two large Pliocene shield volcanoes - Wai'anae and Ko'olau (Juvik and Juvik 1998).

The project site is located at the foot of the Ko'olau Mountains. This mountain range was created by the Ko'olau Volcano which formed about 2.2 to 2.5 million years ago (Lau and Mink 2006). Ko'olau is comprised of shield lavas, referred to as Ko'olau Basalt, as well as rejuvenated stages, termed the Honolulu Volcanics (Juvik and Juvik 1998). The Kahuku area of O'ahu has a complex geological history. Eroded shield volcanoes, such as the Ko'olau Volcano, typically have dike complexes of basaltic material associated with active rift zones. These massive sheets of rock extend vertically into the lava flows, inhibiting normal groundwater flow (Hunt 1996).



Legend

Wetland Survey Points

TMK Parcel 56005007

TMK Parcels

USFWS Wetland Inventory/ Cowardin Classification

James Campbell National Wildlife Refuge

Hydrology

AQUEDUCT

DITCH OR CANAL

FLUME

SIPHON

STREAM

STREAM, UNDERPASS

Figure 1
Hydrology and Sampling Points at the Kahuku Wind Farm Site

N

0 500 1,000 2,000 ft

0 100 200 400 M

SWCA ENVIRONMENTAL CONSULTANTS
Sound Science. Creative Solutions.®

Source: State of Hawaii GIS; City and County of Honolulu; USGS; USFWS

The majority of the site is underlain Koʻolau Basalt lava flows ranging from 1.8 to 3 million year old. Near the makai boundary of the property older dune deposits, as well as lagoon and reef deposits (limestone and mudstone) are present. In addition, a narrow strip of alluvium sand and gravel underlies a portion of the property, roughly bisecting the middle of the parcel. No unique or unusual geologic resources or conditions are known to occur onsite.

Soils on the island of Oʻahu were classified and defined by the U.S. Department of Agriculture (USDA) Soil Conservation Service (Foote et al. 1972) and Natural Resource Conservation Service (NRCS). According to the NRCS National Hydric Soils List, none of the soils on the unit are considered hydric. Soil types and features identified by the USDA on the property are listed in Table 2.

Table 2. Soil types found on the Firstwind property based on classifications from Foote et al. (1972).

Soil Type		Key Characteristics	Percent
PeC	Paumalu silty clay, 8 to 15 percent slopes	Permeability: moderately rapid; Runoff: slow to medium; Erosion: slight to moderate	19.26%
LaB	Lahaina silty clay, 3 to 7 percent slopes	Permeability: moderate; Runoff: slow; Erosion: slight.	17.43%
LaC	Lahaina silty clay, 7 to 15 percent slopes	Permeability: moderate; Runoff: medium; Erosion: moderate.	16.53%
CR	Coral Outcrop	--	11.46%
PeB	Paumalu silty clay, 3 to 8 percent slopes	Permeability: moderately rapid; Runoff: slow Erosion: slight	10.14%
PZ	Paumalu-badland complex	Permeability: moderately rapid; Runoff: medium to rapid; Erosion: moderate to severe.	5.55%
PeD	Paumalu silty clay, 15 to 25 percent slopes	Permeability: moderately rapid; Runoff: medium; Erosion: moderate.	4.68%
PeE	Paumalu silty clay, 25 to 40 percent slopes	Permeability: moderately rapid; Runoff: medium to rapid; Erosion: moderate to severe.	3.78%
KaC	Kaena clay, 6 to 12 percent slopes	Permeability: slow; Runoff: slow to medium; Erosion: slight to moderate.	3.60%
KPZ	Kemoo-badland complex	Permeability: moderate/moderately rapid; Runoff: medium to rapid; Erosion: moderate to severe.	1.77%
KanE	Kaena very stony clay, 10 to 35 percent slopes	Permeability: slow; Runoff: medium to rapid; Erosion: moderate to severe.	1.30%
KpD	Kemoo silty clay, 12 to 20 percent slopes	Permeability: moderate/moderately rapid; Runoff: medium; Erosion: moderate.	1.24%
HeB	Haleiwa silty clay, 2 to 6 percent slopes	Permeability: moderate; Runoff: slow; Erosion: slight.	0.81%
WkB	Waialua silty clay, 3 to 8 percent slopes	Permeability: moderate; Runoff: slow; Erosion: slight.	0.79%
KaeC	Kaena stony clay, 6 to 12 percent slopes	Permeability: slow; Runoff: slow to medium; Erosion: slight to moderate.	0.60%

W	Water > 40 acres*	--	0.48%
PeF	Paumalu silty clay, 40 to 70 percent slopes	Permeability: moderately rapid; Runoff: rapid; Erosion: severe.	0.31%
WkA	Waialua silty clay, 0 to 3 percent slopes	Permeability: moderate; Runoff: slow; Erosion: slight.	0.21%
KpC	Kemoo silty clay, 6 to 12 percent slopes	Permeability: moderate/moderately rapid; Runoff: medium; Erosion: slight to moderate.	0.06%

2.3 Hydrology and Drainage

Hydrologic processes in Hawaiʽi are often highly dependent on the climatic and geological features of the area. For example, stream flow is influenced by rainfall and wind patterns. The majority of the perennial streams (84 percent) on Oʽahu are located in the Koʽolau Mountains because the prevailing trade wind patterns produce a larger amount of precipitation compared to the leeward side of the island (Polhemus 2007). In addition, permeable underlying rock may cause some streams on Oʽahu to have lengthy dry reaches under natural conditions.

Streams in the Kahuku area are considered to be naturally intermittent (Polhemus et al. 1992) and are typically short and steep, with permeable upland soils creating rapid infiltration into the Koʽolau aquifer. As a result, streamflow in the lowland areas near the NWR have periods of high peak floods and little base flow (Hunt and De Carlo 2000). Ohiaʽai, Kalaeokahipa, and Hoolapa are intermittent streams in the Kahuku area (Smith, Young & Assoc. 1990). Ohiaʽai Gulch, which is referred to as Kiʽi ditch/stream makai of Kamehameha Highway, has a drainage area of 2.48 mi^2 and enters the western portion of the Kiʽi Unit. Kalaeokahipa Gulch flows east into the Kiʽi Unit of the NWR and has a drainage area of 1.04 mi^2 (Hunt and De Carlo 2000). Nudist Camp Road Ditch drains a 0.022 mi^2 into the Punamano Unit of the refuge. Nearby Hoolapa Gulch drains west into Punahoolapa marsh, located west of the NWR (Hunt and De Carlo 2000) (Figure 1).

In the late 1970s the U.S. Fish and Wildlife Service Division of Ecological Services biologists used orthophoto quadrangle maps and spot field checks to map wetlands in Hawaiʽi as a part of the National Wetlands Inventory (NWI) Program according to the Cowardin et al. (1979) classification system. In the generalized wetland maps prepared by the NWI, a single wetland types was identified within the project area: palustrine, forested, broad-leafed evergreen, seasonal (PFO3C) wetlands.

The Flood Insurance Rate Maps (FIRM) prepared by the Federal Emergency Management Agency's National Flood Insurance Program depicts flood hazard areas through the state. The maps classify land into four zones depending on the expectation of flood inundation. The site is located in Flood Zone D (undetermined); however, the property is known to have a tendency to flood. The applicant is working to alter the current system by establishing drainage ditches (USFWS 2007).

2.4 Flora and Fauna

The majority of the project area (about 80%) is covered with dense brush and trees, with smaller open areas vegetated with grasses and herbaceous species (Hobdy 2007). The abundant and common species are non-native plants and few native plant species exist onsite as a result of topsoil disturbance from sugar production and cattle grazing. Native species are generally located on rocky outcrops and on the exposed ridge tops in the upper portion of the property.

A total of 18 bird species have been recorded within the Kahuku site (SWCA, unpub. data). Several of these birds are protected under the Migratory Bird Treaty Act (MTBA), including the great frigate bird (*Fregata minor*), Pacific golden plover (*Pluviaslis dominica*) and ruddy turnstone (*Arenaria interpres*).

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* Land uses on the property since the publication of these soils classifications in 1972 likely altered the hydrology of the site; no standing water was observed at these locations during the surveys.

No federally listed endangered, threatened, or candidate species presently occur on the site; however, several endangered and threatened bird species are known to occur on adjacent properties. This includes four species of endangered waterbirds: the Hawaiian duck (*Anas wyvilliana*) or koloa maoli, the Hawaiian coot (*Fulica alai*) or ʽala ekeʽokeʽo, the Hawaiian common moorhen (*Gallinula chloropus sandvicensis*) or ʽalae ʽula, and the Hawaiian stilt (*Himantopus mexicanus knudseni*) or aeʽo.

2.5 Land Use

The project site was used for sugar production during the late 1800's. Since sugar cultivation ended in roughly the late 1900's, the area has primarily been used for cattle grazing (Hobdy 2007).

Under The State Land Use Law (Act 187), Hawaii Revised Statute Chapter 205, all lands and waters in the State are classified into four districts: Agriculture, Rural, Conservation, and Urban. Conservation Districts, under the jurisdiction of DLNR, are further divided into five subzones: Protective, Limited, Resource, General and Special (Hawaii Administration Rules, Title 13, Chapter 5). The State of Hawaiʽi Land Use District Boundaries are governed by the City and County Land Use Ordinance. The area is designated as an Agricultural district by the State of Hawaii Land Use District Boundaries Map.

In addition, land use is dictated by zoning ordinances from the City and County. The City and County of Honolulu zoning ordinance defines the area as AG-1 Restrict Agricultural District. This designation is intended to preserve "important agricultural lands" for agricultural functions such as the production of food, feed, forage, fiber crops and horticultural plants (City and County of Honolulu, Land Use Ordinance, Chapter 21). A wind farm is permitted in this zoning area with a Conditional Use Permit (CUP) (USFWS 2007).

3.0 METHODOLOGY

SWCA employed methods for determining the presence of wetlands and delineating wetland boundaries prescribed by the *Army Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987, updated online version) as required by the Honolulu District, US Army Engineers and the City and County of Honolulu. Wetland delineation fieldwork was conducted by SWCA biologists and staff on June 4-5 and June 16, with supplemental data collected on October 6, 2008. Wetland determination data sheets prepared on these dates appear in Appendix A.

All low lying areas and intermittent streams on the Firstwind project site at Kahuku were walked through on June 4-5 and June 16, 2008 to determine the presence of wetlands based upon the three wetland criteria: a predominance of hydrophilic vegetation, hydric soils, and wetland hydrology (COE 1987). Numbered sampling points and soil cores were established in areas where the NWI had identified wetlands on October 6, 2008 (Figure 1).

3.1 Vegetation

Individual plants species and floral communities were identified throughout the property. In addition, the dominant plant species was recorded at each of the four sampling points. Species cumulatively exceeding 50% of the total cover and those with 20% of the total percent cover were considered dominant. These species were then compared with the regional indicator designated for the state of Hawaiʽi. Plant taxonomy and synonymy follows Wagner et al. (1999).

3.2 Soils

Soils were obtained by digging test pits and taking sediment cores at each of the sampling points. SWCA biologists identified soil samples in the field with standardized color chips (*Munsell Soil Color Charts*, Kollmorgen Corporation, 1998 revised washable edition) of hue, value, and chroma and by texture (sand, silt, clay, loam, muck, and peat). Anaerobic soil conditions and the presence of gleyed soils were of particular interest.

3.3 Hydrology

Both primary and secondary hydrology indicators were evaluated at each sampling site. Biologists searched for inundation, saturation, water marks, drift lines, crust, soil cracks, hydrogen sulfide odor, and drainage patterns.

4.0 FINDINGS

4.1 Vegetation

A list of vegetation noted onsite by SWCA and Hobdy (2007) is included in Appendix B. A total of 50 plant species were observed on site. The vegetation in the upland regions of the surveyed area are mostly comprised of dense koa haole (*Leucaena leucocephala*) trees with a mix of grass and herbaceous plants in the understory. Cocklebur (*Xanthium strumarium*), allspice (*Pimenta dioica*) and kolomona (*Senna surattensis*) were some of the other common tree/ shrub species through the surveyed area (Figure 2). Only a few native species were found, such as ‛ala‛ala wai nui (*Peperomia blanda*) and ‛iliee (*Plumbago zeylanica*) on rocky outcrops and ‛akia (*Wikstroemia oahuensis*) and u‛ulei (*Osteomeles anthyllidifolia*) on the exposed ridge tops in the upper portion of the property. The upland region also comprised of some large patches of open and eroded areas with no vegetation other than few herbaceous species such as Jamaican vervain (*Stachytarpheta jamaicensis*), ‛uhaloa (*Waltheria indica*) and *Bidens alba*. There was a plateau region in the southern portion of the property that was mostly an ironwood (*Casuarina equisetifolia*) and sisal (*Agave sisalana*) forest with some ‛akia in the understory.

The vegetation in the ditches and canals and the sediment stream beds was dominated by parasol leaf tree (*Macaranga tanarius*) and ficus species (such as *Ficus macrophylla*), especially along the rocky walls and with relatively few species in the shaded understory. Castor bean (*Ricinus communis*), *Pluchea* species, guinea grass (*Panicum maximum*), and kolomona were also common in the gulch areas, ditches and canals. There was a large patch of hau (*Hibiscus tiliaceus*) and Christmas berry (*Schinus terebinthifolius*) thicket in the gulch area near the confluence of the two streams. The rocky stream beds were mostly dominated by guinea grass with rare occurrence of species such as honohono (*Commelina diffusa*) and coral berry (*Rivina humilis*). *Ficus* species, koa haole and Christmas berry trees mostly dominated the banks of the two streams.

None of the 50 plant species recorded onsite are obligate wetland species. Of the 50 species, 32 species did not occur on the regional list for Hawai‛i – indicating that these are all upland species in Hawai‛i. Based on the National List of Plant Species that Occur in Wetlands: Hawai‛i (Reed 1988), of the remaining 18 species are given the following classification on the regional list: nine species are classified as Facultative Upland (FACU); two species are Facultative Upland with lower frequency of occurrence in wetlands in Hawai‛i (FAC-), two species are Facultative (FAC); two species are Facultative Upland but with tentative assignment due to lack of information (FACU*), 1 Facultative with tentative assignment due to lack of information (FAC*) and 2 species with no information to determine indicator status (NI).

4.2 Soils

None of the soils on the unit are considered hydric and no hydric soil conditions were observed during the surveys.

4.3 Hydrology

Only one small wetted area was found by SWCA during the surveys. The ponded area was located in the upper portion of Ohia‛ai Gulch, just below Sampling Point 4 (Figure 1). On June 4, 2008, this less than 1 sq. meter area bounded by several medium sized boulders had approximately 3 inches of water. On the previous survey dates, no water was present in this depression, although water marks were evident on the boulders (Figure 3). Except in this small area, no flooding or ponding was observed on the parcel in the gulches or in other areas of the parcel.

Figure 2. Typical vegetation on the Firstwind property.

Figure 3. Small wetted area in the upper portion of Ohia‘ai Gulch.

4.4 Sampling points

Four sampling points were studied by SWCA on October 6, 2008 (Figure 1). SWCA assigned a number to each of the areas and documented the three criteria, as explained in section 3.0. Each sampling point is described below and the dominant plant species present at each site are followed by the regional indicator status, as described in Table 1.

Sampling Point 1

Sampling Point 1 is located in the vicinity of the former aqueduct, as indicated on the 1998 USGS Kahuku Quad map. This point is found along the southern boundary of the property. Koa haole (*Leucaena leucocephala*) (UPL), allspice (*Pimenta dioica*) (--),† kolomona (*Senna surattensis*) (UPL), and guinea grass (*Panicum maximum*) (FACU) are the dominate plant species at this site (Figure 4). Although the USDA Soil Conservation Service (Foote et al. 1972) defines this area as water, no water or hydric soils were observed in this location. A test pit dug to a depth of 35.6 cm (14 in) and a soil core to a depth of 20 cm (7.9 in) revealed very fine soil, with a 7.5 YR hue, value of 2.5, and a chroma of 3 (7.5 YR 2.5/3) (Figures 5 and 6). The soil has a high iron content as indicated by its red color. No hydrology indicators were present at the site.

Sampling Point 2

Sampling Point 2 is located in the lower reaches of Ohiaʻai Gulch along the eastern property boundary. A large coral outcrop area lies adjacent to this site. The dominant plants in this area include the following: guinea grass (FACU), hau (*Hibiscus tiliaceus*) (FACW), koa haole (UPL), and Moreton Bay fig (*Ficus macrophylla*) (--) (Figure 7). Soils at 12 cm (4.7 in) and 38 cm (15 in) below the surface were generally found to be 2.5 YR, with both a value and chroma of 3 (2.5 YR 3/3) (Figures 8 and 9). The drainage area is conspicuous due to the de-vegetated stream bed contrasting the raised stream banks lined with dense strands of guinea grass. No water was present in the stream bed and the presence of debris and small koa haole seedlings suggest there has not been a recent flow at this location.

Figure 4. Sampling Point 1.

† (--) means that the indicator status was not included in the 1996 National Summary List for Hawaiʻi.

Figure 5. Soil core at Sampling Point 1.

Figure 6. Soil pit dug at Sampling Point 1.

Figure 7. Sampling Point 2.

Figure 8. Soil core at Sampling Point 2.

Figure 9. Soil pit dug at Sampling Point 2.

Sampling Point 3

Sampling Point 3 is located at the bottom of Kalaeokahipa Gulch at an elevation of roughly 93 ft. Cocklebur (*Xanthium strumarium*), guinea grass (FACU), Jamaican vervain (*Stachytarpheta jamaicensis*) (FACU), *Sida rhombifolia* (FACU), Bermuda grass (*Cynodon dactylon*) (FACU), and pea aubergine (*Solanum torvum*) (--) are the dominant plant species (Figure 10). According to Foote et al. (1972), the soils at this location are considered Lahaina silty clay, 3 to 7 percent slopes. Coring and pit digging (Figure 11) to a depth of 14 cm (5.5 in) and 28 cm (11 in), respectively, revealed a middle yellow-red hue, with a value of 3 and a chroma of 3 (5 YR 3/3). Similar to Sampling Point 1, the soil at this site contains a large amount of iron oxide. The drainage area is demarcated by the lower lying stream bed compared to the elevated banks. However, it is not likely that this area has flowed recently due to the presence of mature vegetation in the stream bed.

Sampling Point 4

Sampling Point 4 is located with Ohia‘ai Gulch, further upstream from Sampling Point 2, near the southeastern corner of the property. The dominant vegetation at the site is guinea grass (FACU), koa haole (UPL), and Christmas berry (*Schinus terebinthifolius*) (FACU-). The stream bed in this area is mostly lined with large pebbles and small boulders (Figure 12). A soil core and test pit was possible in a clear area of the stream bed (Figures 13 and 14). Soils at 12 cm (4.7 in) and 25.4 cm (10 in) below the surface had a middle yellow-red hue, with a value of 5 and a chroma of 4 (5 YR 5/4). Highly exposed koa haole tree roots were present along the elevated stream banks (Figure 15). The stream bed was largely devoid of vegetation.

5.0 UPLANDS

None of the areas on the parcel meet the criteria for hydrophilic vegetation, hydric soils, and wetland hydrology; therefore, the entire project parcel is considered upland.

Figure 10. Sampling Point 3, showing elevated stream bank on right.

Figure 11. Soil pit dug at Sampling Point 3.

Figure 12. Sampling Point 4.

Figure 13. Soil core at Sampling Point 4.

Figure 14. Soil pit dug at Sampling Point 4.

Figure 15. Exposed koa haole tree roots along the elevated banks of Ohiaʻai Gulch.

6.0 CONCLUSION

Wetlands and waters (streams) of the U.S. are regulated by the U.S. Army Corps of Engineers (Corps) under Section 404 of the Clean Water Act. The following are considered jurisdictional waters and are therefore subject to agency authority:

- Traditional navigable waters (TNW);
- Wetlands adjacent to TNW;
- Non-navigable tributaries of TNW that are relatively permanent where the tributaries typically flow year-round or have continuous flow at least seasonally;
- Wetlands that directly abut such tributaries.

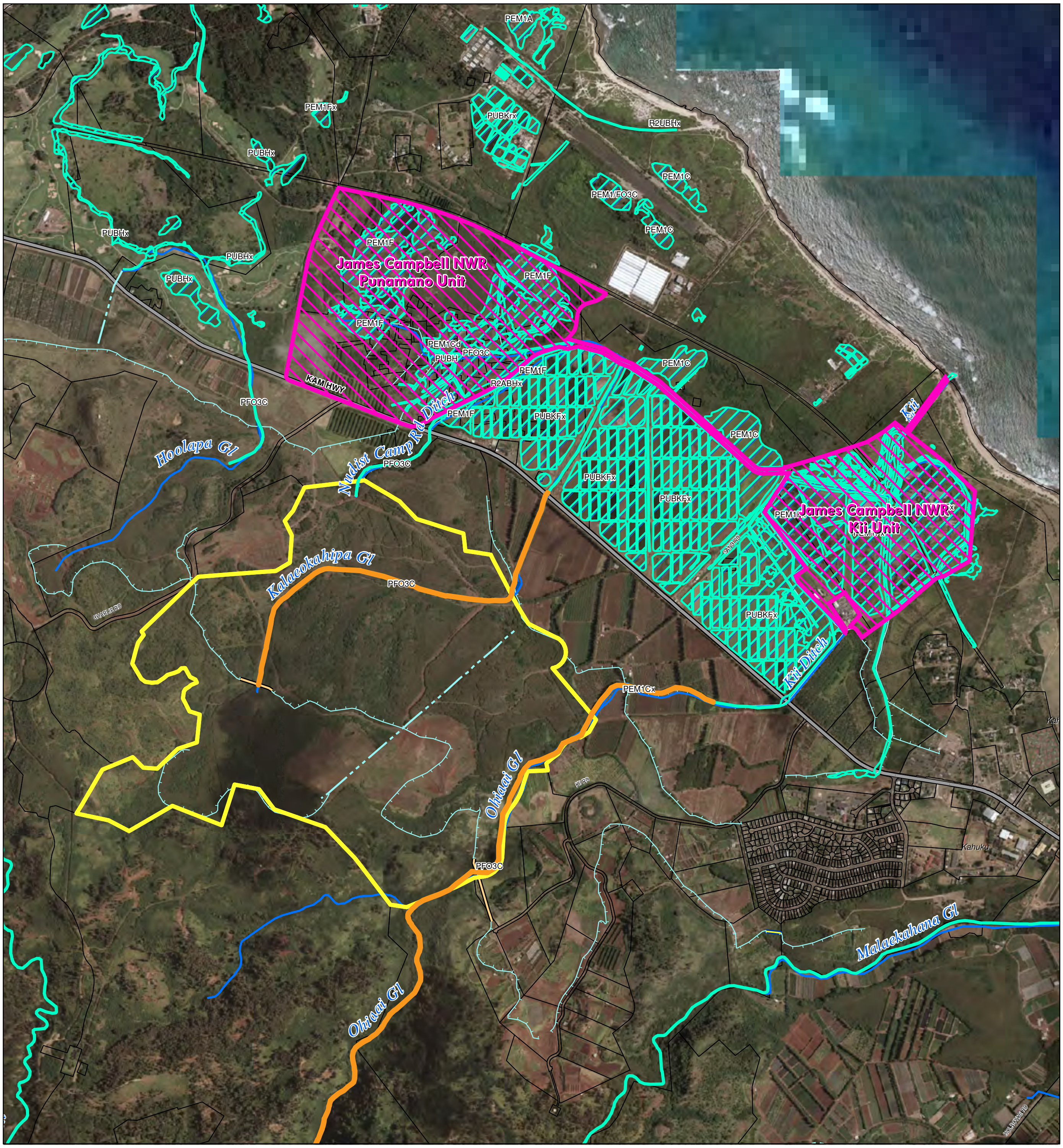
Per the Rapanos v. United States Supreme Court Decision and Solid Waste Agency of Northern Cook County (SWANCC) v. U.S. Army Corps of Engineers Supreme Court Decision, waters are also considered jurisdictional if they have a "significant nexus" with a TNW. A significant nexus is determined by assessing if the flow characteristics and function of the tributary and the functions performed by wetlands adjacent to the tributary significantly affect the chemical, physical, and biological integrity of the downstream TNW.

No wetlands meeting the three established criteria of hydrophilic vegetation, soils, and water regime were found to occur within the project parcel. In addition, streams and tributaries within the property are intermittent and therefore do not have continuous or seasonal flow.

The two intermittent streams, Ohia'ai Gulch and Kalaeokahipa Gulch, may be subject to discretionary Department of the Army jurisdiction due to their "significant nexus" with the traditional navigable waters of the James Campbell National Wildlife Refuge (Hunt and DeCarlo 2000) (Figure 16). Any proposed impacts jurisdictional wetlands or waters identified in this report will require submittal of a wetland removal/fill permit application and a wetland mitigation plan to the Honolulu District, US Army Engineers.

7.0 LIMITATIONS

The services provided under this contract as described in this report include professional opinions and judgments based on data collected. These services were provided according to generally accepted practices of the environmental profession. The methodology for determining the presence of wetlands and delineating wetland boundaries follows the routine wetland determination methodology and plant community approach of the Army Corps of Engineers Wetlands Delineation Manual (1987, updated online version). The conclusions drawn in this report represent our best professional judgment after examination of the site conditions and background information. SWCA recommend that our report be submitted to Honolulu District, US Army Engineers for certification of our findings.



Legend

TMK Parcel 56005007

TMK Parcels

USFWS Wetland Inventory/ Cowardin Classification

James Campbell National Wildlife Refuge

Hydrology

AQUEDUCT

DITCH OR CANAL

FLUME

SIPHON

STREAM

STREAM, UNDERPASS

Probable jurisdictional wetland based on significant nexus determination by ACOE Honolulu District

Figure 2
Probable Jurisdiction Wetlands at the Kahuku Wind Farm Site

0 500 1,000 2,000 ft

0 100 200 400 M

N

SWCA
ENVIRONMENTAL CONSULTANTS
Sound Science. Creative Solutions.®

Source: State of Hawaii GIS; City and County of Honolulu; USGS; USFWS

8.0 REFERENCES

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DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Kahuku Windfarm Applicant/Owner: Firstwind Investigator: Thair / Taira	Date: 10-6-2008 County: Honolulu State: Hawaii
Do Normal Circumstances exist on the site? Yes No Is the site significantly disturbed (Atypical Situation)? Yes No Is the area a potential Problem Area? Yes No (If needed, explain on reverse.)	Community ID: 1 Transect ID: Plot ID:

@2:40pm

Normal Circumstances: Yes (circled). Significantly disturbed: No (circled). Potential Problem Area: No (circled).

GPS pt. 665

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Leucaena leucocephala		UPL	9.		
2. Senna surattensis		UPL	10.		
3. Pimenta dioica		--	11.		
4. Panicum maximum		FACU	12.		
5.			13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-).

Remarks: mostly bare ground; few understory species

HYDROLOGY

___ Recorded Data (Describe in Remarks):
 ___ Stream, Lake, or Tide Gauge
 ___ Aerial Photographs
 ___ Other
___ No Recorded Data Available

Field Observations:

Depth of Surface Water: ________(in.)

Depth to Free Water in Pit: Ø ________(in.)

Depth to Saturated Soil: ________(in.)

Wetland Hydrology Indicators:
Primary Indicators:
___ Inundated
___ Saturated in Upper 12 Inches
___ Water Marks
___ Drift Lines
___ Sediment Deposits
___ Drainage Patterns in Wetlands
Secondary Indicators (2 or more required):
___ Oxidized Root Channels in Upper 12 Inches
___ Water-Stained Leaves
___ Local Soil Survey Data
___ FAC-Neutral Test
___ Other (Explain in Remarks)

Remarks: old aqueduct site per USGS map

SOILS

Map Unit Name
(Series and Phase): ____________________

Taxonomy (Subgroup): ____________________

Drainage Class: ____________

Field Observations
Confirm Mapped Type? Yes No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/ Size/Contrast	Texture, Concretions, Structure, etc.
20cm		7.5YR 2.5/3			very fine

Hydric Soil Indicators:

___ Histosol
___ Histic Epipedon
___ Sulfidic Odor
___ Aquic Moisture Regime
___ Reducing Conditions
___ Gleyed or Low-Chroma Colors

___ Concretions
___ High Organic Content in Surface Layer in Sandy Soils
___ Organic Streaking in Sandy Soils
___ Listed on Local Hydric Soils List
___ Listed on National Hydric Soils List
___ Other (Explain in Remarks)

Remarks: iron content high
soil pit dug to 14 inches (35.6 cm)

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes No (Circle)
Wetland Hydrology Present? Yes No
Hydric Soils Present? Yes No

(Circle)
Is this Sampling Point Within a Wetland? Yes No

Remarks:

Approved by HQUSACE 3/92

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Kahuku Windfarm Applicant/Owner: Firstwind Investigator: Thalk / Taira	Date: 10-16-2008 @3:06pm County: Honolulu State: HI
Do Normal Circumstances exist on the site? Yes No — Yes Is the site significantly disturbed (Atypical Situation)? Yes No — No Is the area a potential Problem Area? Yes No — No (If needed, explain on reverse.)	Community ID: 2 Transect ID: Plot ID:

GPS pt. 666

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Guinea grass		FACU	9.		
2. Ficus macrophylla		--	10.		
3. Koa haole		UPL	11.		
4. Hibiscus filiaceus		FACW	12.		
5.			13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-).

Remarks:

HYDROLOGY

___ Recorded Data (Describe in Remarks): X Stream, Lake, or Tide Gauge ___ Aerial Photographs ___ Other ___ No Recorded Data Available Field Observations: Depth of Surface Water: Ø ___(in.) Depth to Free Water in Pit: ___(in.) Depth to Saturated Soil: ___(in.)	Wetland Hydrology Indicators: Primary Indicators: ___ Inundated ___ Saturated in Upper 12 Inches ___ Water Marks X Drift Lines ___ Sediment Deposits X Drainage Patterns in Wetlands Secondary Indicators (2 or more required): ___ Oxidized Root Channels in Upper 12 Inches ___ Water-Stained Leaves ___ Local Soil Survey Data ___ FAC-Neutral Test ___ Other (Explain in Remarks)

Remarks: within Ohia'ai Gulch. Panicum maximum along banks, but no water!

Debris within stream bed; but small seedling showing no recent flow

SOILS

Map Unit Name
(Series and Phase): ______________________ Drainage Class: __________
Field Observations
Taxonomy (Subgroup): ______________________ Confirm Mapped Type? Yes No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/ Size/Contrast	Texture, Concretions, Structure, etc.
		2.5YR	3/3		very fine

Hydric Soil Indicators:

___ Histosol
___ Histic Epipedon
___ Sulfidic Odor
___ Aquic Moisture Regime
___ Reducing Conditions
___ Gleyed or Low-Chroma Colors
___ Concretions
___ High Organic Content in Surface Layer in Sandy Soils
___ Organic Streaking in Sandy Soils
___ Listed on Local Hydric Soils List
___ Listed on National Hydric Soils List
___ Other (Explain in Remarks)

Remarks: core to 120 mm (4.7 in)
pit to 15 inches (38 cm)
\+ Iron

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes No (Circle)
Wetland Hydrology Present? Yes No
Hydric Soils Present? Yes No

(Circle)
Is this Sampling Point Within a Wetland? Yes No

Remarks:

Approved by HQUSACE 3/92

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Kahuku Windfarm Applicant/Owner: Firstwind Investigator: Thair / Taira	Date: 10-6-2008 County: Honolulu State: Hawaii
Do Normal Circumstances exist on the site? Yes No Is the site significantly disturbed (Atypical Situation)? Yes No Is the area a potential Problem Area? Yes No (If needed, explain on reverse.)	Community ID: 3 Transect ID: Plot ID:

GPS pt. 667

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Xanthium strumarium		FACU	9.		
2. Sida rhombifolia		FACU	10.		
3. Cynodon dactylon		FACU	11.		
4. Stachytarpheta jamaicensis		FACU	12.		
5. Panicum maximum		FACU	13.		
6. Solanum torvum		--	14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-).

Remarks:

HYDROLOGY

___ Recorded Data (Describe in Remarks):
X Stream, Lake, or Tide Gauge
___ Aerial Photographs
___ Other
___ No Recorded Data Available

Field Observations: very dry

Depth of Surface Water: ______(in.)

Depth to Free Water in Pit: 0 ______(in.)

Depth to Saturated Soil: ______(in.)

Wetland Hydrology Indicators:
Primary Indicators:
___ Inundated
___ Saturated in Upper 12 Inches
___ Water Marks
___ Drift Lines
___ Sediment Deposits
X Drainage Patterns in Wetlands
Secondary Indicators (2 or more required):
___ Oxidized Root Channels in Upper 12 Inches
___ Water-Stained Leaves
___ Local Soil Survey Data
___ FAC-Neutral Test
___ Other (Explain in Remarks)

Remarks: @ bottom of Kalaekahupa gulch

SOILS

Map Unit Name (Series and Phase): ______	Drainage Class: ______
Taxonomy (Subgroup): ______	Field Observations Confirm Mapped Type? Yes No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/ Size/Contrast	Texture, Concretions, Structure, etc.
		5YR 3/3			

Hydric Soil Indicators:

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- ___ Aquic Moisture Regime
- ___ Reducing Conditions
- ___ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ___ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks: core to 14 cm (5.5)
pit to 11 inches (28 cm)
iron

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	Yes No (Circle)		(Circle)
Wetland Hydrology Present?	Yes No		
Hydric Soils Present?	Yes No	Is this Sampling Point Within a Wetland?	Yes No

Remarks:

Approved by HQUSACE 3/92

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

@4:20

Project/Site: Kahuku Windfarm Applicant/Owner: Firstwind Investigator: Thair / Taira	Date: 10-6-2008 County: Honolulu State: HI
Do Normal Circumstances exist on the site? Yes (circled) No Is the site significantly disturbed (Atypical Situation)? Yes No (circled) Is the area a potential Problem Area? Yes No (circled) (If needed, explain on reverse.)	Community ID: 4 Transect ID: Plot ID:

GPS pt. 668

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Guinea grass		FACU	9.		
2. Koa haole		UPL	10.		
3. Schinus terebinthifolius		FACU-	11.		
4.			12.		
5.			13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-).

Remarks:

HYDROLOGY

___ Recorded Data (Describe in Remarks): X Stream, Lake, or Tide Gauge ___ Aerial Photographs ___ Other ___ No Recorded Data Available Field Observations: Depth of Surface Water: ø ______ (in.) Depth to Free Water in Pit: ______ (in.) Depth to Saturated Soil: ______ (in.)	Wetland Hydrology Indicators: Primary Indicators: ___ Inundated ___ Saturated in Upper 12 Inches ___ Water Marks ___ Drift Lines ___ Sediment Deposits ___ Drainage Patterns in Wetlands Secondary Indicators (2 or more required): ___ Oxidized Root Channels in Upper 12 Inches ___ Water-Stained Leaves ___ Local Soil Survey Data ___ FAC-Neutral Test ___ Other (Explain in Remarks)

Remarks: within Ohua'ai Gulch
Tree roots exposed along banks

SOILS

Map Unit Name
(Series and Phase): ______

Taxonomy (Subgroup): ______

Drainage Class: ______
Field Observations
Confirm Mapped Type? Yes No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/ Size/Contrast	Texture, Concretions, Structure, etc.
		5YR 5/4			

Hydric Soil Indicators:

___ Histosol
___ Histic Epipedon
___ Sulfidic Odor
___ Aquic Moisture Regime
___ Reducing Conditions
___ Gleyed or Low-Chroma Colors

___ Concretions
___ High Organic Content in Surface Layer in Sandy Soils
___ Organic Streaking in Sandy Soils
___ Listed on Local Hydric Soils List
___ Listed on National Hydric Soils List
___ Other (Explain in Remarks)

Remarks: core to 12cm (4.7in)
pit to 10 inches (25 cm)
stream bottom mostly lined with rocks

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	Yes No (Circle)	(Circle)
Wetland Hydrology Present?	Yes No	
Hydric Soils Present?	Yes No	Is this Sampling Point Within a Wetland? Yes No

Remarks:

Approved by HQUSACE 3/92

APPENDIX B: LIST OF VEGETATION

This list is adapted from the report on plant survey conducted by Robert Hobdy at the First Wind project site in April 2007. It lists all the species found during the April 2007. The “X” in the second column indicates the species that were found by SWCA during the survey on June 4, 2008. The “XX” indicates the species that were not listed in the April 2007, but were found during the wetland plant survey on June 4, 2008.

Scientific name	Hawaiian, Common name(s)	Found on 6/4/2008	Wetland indicator	Status	Abundance in 4/2007
FERNS					
LINDSAEACEAE (Lindsaea Family)					
Sphenomeris chinensis (L.) Maxon	pala'ā		FAC*	I	rare
NEPHROLEPIDACEAE (Sword Fern Family)					
Nephrolepis exaltata (L.) Schott subsp. *hawaiiensis* W.H.Wagner	ni'ani'au		FAC*	E	rare
POLYPODIACEAE (Polypody Fern Family)					
Phymatosorus grossus (Langsd. & Fisch.) Brownlie	laua'e	**X**		N	rare
CONIFERS					
PINACEAE (Pine Family)					
Pinus caribaea Morelet	Caribbean pine			N	rare
MONOCOTS					
AGAVACEAE (Agave Family)					
Agave sisalana Perrine	sisal	**X**		N	rare
Cordyline fruticosa (L.) A. Chev.	ki	**X**		P	rare
ARECACEAE (Palm Family)					
Cocos nucifera L.	niu	**X**	FACU	P	rare
Phoenix x dactylifera	hybrid date palm	**X**		N	rare
CYPERACEAE (Sedge Family)					
Cyperus rotundus L.	nut-sedge		FACU	N	rare
POACEAE (Grass Family)					
Andropogon virginicus L.	broomsedge		FACU	N	rare
Brachiaria mutica (Forssk.) Stapf	California grass		FACW	N	rare
Chloris barbata (L.) Sw.	swollen fingergrass			N	rare
Chloris divaricata R.Br.	stargrass			N	uncommon
Chrysopogon aciculatus (Retz.) Trin.	pi'i pi'i			I	uncommon
Cynodon dactylon (L.) Pers.	Bermuda grass		FACU	N	uncommon

Dactyloctenium aegytium (L.) Willd.	beach wiregrass			N	rare
Digitaria ciliaris (Retz.) Koeler	Henry's crabgrass		FAC	N	uncommon
Digitaria insularis (L.) Mez ex Ekman	sourgrass	**X**	FACU	N	abundant
Eleusine indica (L.) Gaertn.	wiregrass		FACU-	N	uncommon
Eragrostis amabilis (L.) Wight & Arnott	Japanese lovegrass			N	rare
Eragrostis pectinacea (Michx.) Nees	Carolina lovegrass			N	rare
Panicum maximum Jacq.	Guinea grass	**X**	FACU	N	uncommon
Paspalum conjugatum Bergius	Hilo grass		FAC+	N	rare
Paspalum dilatatum Poir.	Dallis grass		FACU	N	uncommon
Paspalum fimbriatum Kunth	Panama paspalum		FAC	N	rare
DICOTS					
ACANTHACEAE (Acanthus Family)					
Asystasia gangetica (L.) T.Anderson	Chinese violet	**X**		N	common
AMARANTHACEAE (Amaranth Family)					
Achyranthes aspera L.	chirchita			N	uncommon
Alternanthera pungens Kunth	khaki weed			N	rare
Amaranthus spinosus L.	spiny amaranth	**X**	FACU-	N	uncommon
Amaranthus viridis L.	slender amaranth		FAC	N	rare
ANACARDIACEAE (Mango Family)					
Magnifera indica L.	mango		FACU	N	rare
Schinus terebinthifolius Raddi	Christmas berry	**X**	FACU-	N	common
APIACEAE (Parsley Family)					
Centella asiatica (L.) Urb.	Asiatic pennywort	**X**	FAC	N	rare
Ciclospermum leptophyllum (Pers.) Sprague	fir-leaved celery		NI	N	rare
ASTERACEAE (Sunflower Family)					
Acanthospermum australe (Loefl.) Kuntze	spiny bur			N	rare
Ageratum conyzoides L.	maile hohono		FAC*	N	uncommon
Bidens alba (L.) DC	common beggarticks	**X**		N	common
Calyptocarpus vialis Less.	straggler daisy			N	uncommon

Conyza bonariensis (L.) Cronquist	hairy horseweed	**X**		N	rare
Crassocephalum crepidioides (Benth.)S.Moore	red flower ragleaf		FAC	N	rare
Cyanthillium cinereum (L.) H. Rob.	little ironweed			N	rare
Emilia fosbergii Nicolson	red pualele			N	rare
Pluchea carolinensis (Jacq.) G.Don	sourbush	**X**		N	common
Pluchea indica (L.) Less.	Indian fleabane		FAC*	N	rare
Pluchea x foxbergii T.S. Cooper & M.M. Galang.		**XX**	FAC*	N	uncommon
Synedrella nodiflora (L.) Gaertn.	nodeweed		FAC*	N	rare
Verbesina encelioides (Cav.) Benth.&Hook.	golden crown-beard		FACU-	N	rare
Xanthium strumarium L.	cocklebur	**X**	FACU	N	uncommon
BIGNONIACEAE (Bignonia Family)					
Spathodea campanulata P.Beauv.	African tulip tree			N	rare
BORAGINACEAE (Borage Family)					
Heliotropium procumbens Mill.	clasping heliotrope			N	rare
BRASSICACEAE (Mustard Family)					
Lepidium virginicum L.	peppergrass			N	rare
CARICACEAE (Papaya Family)					
Carica papaya L.	papaya	**X**		N	rare
CASUARINACEAE (She-oak Family)					
Casuarina equisetifolia Stickm.	common ironwood	**X**		N	uncommon
CHENOPODIACEAE (Goosefoot Family)					
Chenopodium murale L.	'aheahea		FACU	N	rare
CONVOLVULACEAE (Morning Glory Family)					
Ipomoea obscura (L.) Ker-Gawl.	---------------			N	rare
COMMELINACEAE					
Commelina diffusa N.L. Burm.,	honohono	**XX**	FACW	N	rare
EUPHORBIACEAE (Spurge Family)					
Aleurites moluccana (L.) Willd.	kukui	**X**		P	rare

Chamaesyce hirta (L.) Millsp.	hairy spurge	**X**		N	rare
Chamaesyce hypericifolia (L.) Millsp.	graceful spurge	**X**		N	rare
Chamaesyce prostrata (Aiton.) Small	prostrate spurge			N	rare
Macaranga tanarius (L.) Mull. Arg.	parasol leaf tree	**X**		N	common
Phyllanthus debilis Klein ex Willd.	niruri			N	uncommon
Ricinus communis L.	Castor bean	**X**	FACU	N	rare
FABACEAE (Pea Family)					
Acacia confusa Merr.	Formosa koa			N	rare
Acacia farnesiana (L.) Willd.	klu			N	uncommon
Chamaecrista nictitans (L.) Moench	partridge pea			N	uncommon
Crotalaria incana L.	fuzzy rattlepod			N	rare
Crotalaria pallida Aiton	smooth rattlepod			N	rare
Crotalaria retusa L.	rattleweed			N	rare
Desmanthus pernambucanus (L.) Thellung	slender mimosa			N	uncommon
Desmodium incanum DC.	ka'imi clover			N	uncommon
Desmodium triflorum (L.)	three-flowered beggarweed	**X**	FACU*	N	rare
Erythrina variegata L.	tiger claw			N	rare
Indigofera hendecaphylla Jacq.	creeping indigo			N	rare
Leucaena leucocephala (Lam.) de Wit	koa haole	**X**		N	abundant
Macroptilium lathyroides (L.) Urb.	wild bean			N	rare
Medicago lupulina L.	black medick			N	rare
Mimosa pudica L.	sensitive plant	**X**	FACU	N	uncommon
Neonotonia wightii (Wight&Arnott) Lackey	glycine			N	rare
Samanea saman (Jacq.) Merr.	monkeypod	**X**		N	rare
Senna occidentalis (L.) Link	coffee senna	**X**		N	uncommon
Senna surratensis (N.L.Burm.) H.Irwin&Barneby	kolomona	**X**		N	common
Stylosanthes fruticosa (Retz.) Alston	shrubby pencilflower			N	uncommon
LAMIACEAE (Mint Family)					
Leonotis nepetifolia (L.) R.Br.	lion's ear	**X**	NI	N	uncommon
Ocimum gratissimum L.	wild basil			N	rare

MALVACEAE (Mallow Family)					
Abutilon grandifolium (Willd.) Sweet	hairy abutilon	**X**		N	rare
Malva parviflora L.	cheeseweed			N	rare
Malvastrum coromandelianum (L.) Garcke.	false mallow		FACU	N	uncommon
Sida ciliaris (L.) D.Don	fringed fan petals	**X**		N	uncommon
Sida rhombifolia L.	Cuban jute	**X**	FACU	N	uncommon
Sida spinosa L.	prickly sida		NI	N	uncommon
Hibiscus tiliaceus L.	hau	**XX**	FACW	I	rare
MELASTOMATACEAE (Melastoma Family)					
Clidemia hirta (L.) D.Don	Koster's curse	**X**	FACU	N	rare
MENISPERMACEAE (Moonseed family)					
Cocculus trilobus (Thunb.) DC	Huehue	**XX**		I	
MORACEAE (Fig Family)					
Ficus macrophylla Desf. ex Pers.	Moreton Bay fig	**X**		N	rare
Ficus microcarpa L.fil.	Chinese banyan	**X**		N	rare
Ficus platypoda A.Cunn.ex Miq.	rock fig			N	uncommon
MYRSINACEAE (Myrsine Family)					
Ardisia elliptica Thunb.	shoebutton ardisia		FACU	N	rare
MYRTACEAE (Myrtle Family)					
Pimenta diocia (L.) Merr.	allspice	**X**		N	common
Psidium cattleianum Sabine	strawberry guava	**X**	FACU	N	rare
Psidium guajava L.	guava	**X**	FACU	N	uncommon
Syzygium cumini (L.) Skeels	Java plum	**X**		N	uncommon
NYCTAGINACEAE (Four-o'clock Family)					
Bougainvillea spectabilis Willd.	bougainvillea			N	rare
OXALIDACEAE (Wood Sorrel Family)					
Oxalis corniculata L.	'ihi'ai		FACU	P	uncommon
Oxalis debilis Kunth	pink wood sorrel			N	rare
PASSIFLORACEAE (Passion Flower Family)					

Passiflora edulis Sims	passion fruit	**X**		N	rare
Passiflora suberosa L.	corkystem passion flower			N	uncommon
PHYTOLACCACEAE (Pokeweed Family)					
Rivina humilis L.	coral berry			N	uncommon
PIPERACEAE (Pepper Family)					
Peperomia blanda Kunth var floribunda (Miq.) H.Huber	ala'alawainui	**X**		I	rare
PLANTAGINACEAE (Plantain Family)					
Plantago lanceolata L.	narrow-leaved plantain		FACU	N	uncommon
PLUMBAGINACEAE (Plumbago Family)					
Plumbago zeylanica L.	'ilie'e	**X**		I	rare
POLYGALACEAE (Milkwort Family)					
Polygala paniculata L.	milkwort		FACU*	N	rare
POLYGONACEAE (Buckwheat Family)					
Antigonon leptopus Hook & Arnott	Mexican creeper			N	rare
Rumex obtusifolius L.	bitter dock		FAC	N	rare
PRIMULACEAE (Primrose Family)					
Anagallis arvensis L.	scarlet pimpernel			N	rare
ROSACEAE (Rose Family)					
Osteomeles anthyllidifolia (Sm.) Lindl.	u'ulei	**X**		I	rare
RUBIACEAE (Coffee Family)					
Morinda citrifolia L.	noni	**X**	NI	P	rare
Spermacoce assurgens Ruiz & Pav.	buttonweed			N	rare
RUTACEAE (Rue Family)					
Citrus aurantiifolia (Christm.) Swingle	lime			N	rare
SAPOTACEAE (Sapodilla Family)					
Chrysophyllum oliviforme L.	satin leaf			N	uncommon
SOLANACEAE (Nightshade Family)					
Capsicum frutescens L.	chili pepper			N	rare
Solanum americanum Mill.	popolo			I	rare
Solanum torvum Sw.	pea aubergine			N	common
STERCULIACEAE (Cacao					

Family)					
Waltheria indica L.	'uhaloa	**X**		I	uncommon
THYMELAEACEAE ('Akia Family)					
Wikstroemia oahuensis (A. Gray) Rock	'akia	**X**	FAC	E	uncommon
TILIACEAE (Linden Family)					
Triumfetta rhomboidea Jacq.	diamond burrbark			N	rare
Triumfetta semitriloba Jacq.	Sacramento bur			N	uncommon
VERBENACEAE (Verbena Family)					
Lantana camara L.	lantana	**X**		N	common
Stachytarpheta cayennensis (Rich.) Vahl	nettle-leaved vervain			N	uncommon
Stachytarpheta jamaicensis (L.) Vahl	Jamaican vervain	**X**	FACU*	N	common
Verbena litoralis Kunth.	ha'u owi	**X**		N	rare

Appendix 3

FINAL REPORT

RESULTS OF ENDANGERED SEABIRD AND HAWAIIAN HOARY BAT SURVEYS ON NORTHERN OAHU ISLAND, HAWAII, OCTOBER 2007 AND JULY 2008

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NEWTON, MASSACHUSETTS

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FAIRBANKS, ALASKA ♦ FOREST GROVE, OREGON

RESULTS OF ENDANGERED SEABIRD AND HAWAIIAN HOARY BAT SURVEYS ON NORTHERN OAHU ISLAND, HAWAII, OCTOBER 2007 AND JULY 2008

FINAL REPORT

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EXECUTIVE SUMMARY

- FirstWind, LLC, is interested in developing a windfarm on northern Oahu Island, Hawaii. This report summarizes the results of a radar and audio-visual study of seabirds and bats conducted there in fall 2007 and summer 2008. The objectives of this study were to: (1) conduct surveys of endangered seabirds (Hawaiian Petrels *Pterodroma sandwichensis* and Newell's Shearwaters *Puffinus auricularis newelli*) and Hawaiian Hoary Bats (*Lasiurus cinereus semotus*); (2) obtain preliminary information to help assess use of the area by these species; and (3) assess possible fatality rates of these species at this proposed windfarm.
- Two observers monitored movements of seabirds and bats at the Kahuku Study Site, following standard ornithological radar and audio-visual techniques used in previous studies, for 5 nights in October 2007 and for 7 nights and mornings in July 2008.
- Seabird passage rates were extremely low (0.2 targets/h in the summer and 0.3 targets/h in the fall), both overall and relative to other locations in the Hawaiian Islands.
- Flight directions of petrel/shearwater targets were extremely consistent and oriented along a southeast–northwest axis of ~145–325°; only one of nine targets was flying in a direction other than this axis. Nearly all targets that were heading seaward crossed the proposed windfarm site itself, with only one skirting the northeastern boundary of the site.
- The timing of movements suggested that all of the radar targets were those of Newell's Shearwaters.
- We did not see any petrels or shearwaters during the audiovisual sampling, so we were unable to collect data on flight altitude of birds in the study area. In modeling analyses, we assumed that shearwaters in the study area flew at altitudes similar to those on the other Hawaiian Islands.
- We recorded Hawaiian Hoary Bats during the audiovisual sampling, but their movement rates were extremely low (0.0004 bats/h).
- The consistency of flight directions and the presence of safe (so steep that it provides some protection from ground-based predators) and appropriate (uluhe ferns) nesting habitat for Newell's Shearwaters in the area where the radar targets were flying into and out of suggest that there is at least one small colony of Newell's Shearwaters in the northeastern Koolau Range between Kahuku and Laie. There also are numerous records of Newell's Shearwaters in the Koolau Range in the past 30 years, again suggesting persistent nesting colonies in that area.
- We calculated exposure rates and estimated that 1.46 Newell's Shearwaters will fly within the space occupied by a guyed met tower in an average year and that 0.39–3.81 Newell's Shearwaters will fly within the space occupied by a proposed wind turbine in an average year.
- We made some calculations to explore what level of collision-caused fatalities might occur at each of the three met towers at the Kahuku site. By using a range of assumptions for avoidance rates in our fatality models (i.e., 50%, 95%, and 99% avoidance), we estimate fatality of 0.014–0.692 Newell's Shearwaters/met tower/yr and 0.004–0.273 Newell's Shearwaters/wind turbine/yr, depending on the collision-avoidance rate.
- We caution that these assumptions are not based on empirical data. Currently, the limited avoidance data available for these and other bird species suggest that the proportion of petrels that see and avoid the met towers will be substantial and will be enhanced by marking, but we emphasize that, until data are available on petrel and shearwater avoidance behavior at met towers with marked guy wires, the exact proportion will remain unknown.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

We thank FirstWind, LLC, for funding this study. We especially thank Gregory Spencer and Ian Bordenave, both of FirstWind, who helped with all of the field work. We also thank Dave Cowan and Gregory Spencer of FirstWind for their help with logistical matters. At ABR, we thank Allison Zusi-Cobb, Julie Parrett, and Will Lentz for GIS work; Thomas DeLong for fiscal assistance; and Pam Odom for report preparation. This report has been improved by the reviews of David Cowan and Gregory Spencer.

INTRODUCTION

FirstWind, LLC, is interested in developing a wind-energy facility (hereafter, windfarm) near Kahuku, on northern Oahu Island, Hawaii. As part of the siting process, FirstWind wanted to obtain information on endangered seabirds and bats in the vicinity of this proposed windfarm. Because ornithological radar and night-vision techniques have been shown to be successful in studying these species on Kauai (Cooper and Day 1995, 1998; Day and Cooper 1995, Day et al. 2003b), Maui (Cooper and Day 2003), Molokai (Day and Cooper 2002), and Hawaii (Reynolds et al. 1997, Day et al. 2003a), we used them to survey seabirds in the vicinity of the proposed Oahu windfarm. This report summarizes the results of a radar and visual study of seabirds and bats conducted in this area in October (fall) 2007 and early July (summer) 2008. The objectives of this study were to: (1) conduct surveys of endangered seabirds and bats in the vicinity of the proposed windfarm; (2) summarize available information to help assess use of the area by these species; and (3) assess possible fatality rates of these species at this proposed windfarm.

BACKGROUND

Two seabird species that are protected under the Endangered Species Act are likely to occur in the Oahu study area: the endangered Hawaiian Petrel (*Pterodroma sandwichensis*; 'Ua'u) and the threatened Newell’s (Townsend's) Shearwater (*Puffinus auricularis newelli*; 'A'o). Both of these species are forms of tropical Pacific species that nest only on the Hawaiian Islands (AOU 1998), and both are Hawaiian endemics whose populations have declined significantly in historical times: they formerly nested widely over all of the Main Islands but now are restricted in most cases to scattered colonies in more inaccessible locations (Ainley et al. 1997b, Simons and Hodges 1998). The main exception is Kauai Island, which has no introduced Indian Mongooses (*Herpestes auropunctatus*); there, colonies still are widespread and populations are substantial in size.

The Hawaiian Petrel nests on several of the Main Hawaiian Islands (Harrison et al. 1984, Harrison 1990) but is known to nest primarily on Maui (Richardson and Woodside 1954, Banko 1980a; Simons 1984, 1985; Simons and Hodges 1998, Cooper and Day 2003) and Lanai (Shallenberger 1974; Hirai 1978a, 1978b; Conant 1980; J. Penniman, State of Hawaii, DOFAW, pers. comm.) and, to a lesser extent, on Kauai (Telfer et al. 1987, Gon 1988; Ainley et al. 1995, 1997a, 1997b; Day and Cooper 1995, Day et al. 2003a) and Hawaii (Banko 1980a, Conant 1980, Hu et al. 2001, Day et al. 2003a). Recent information from Molokai (Simons and Hodges 1998, Day and Cooper 2002) also suggests breeding.

The Newell's Shearwater nests on several of the Main Hawaiian Islands (Harrison et al. 1984, Harrison 1990), with the largest numbers clearly occurring on Kauai (Telfer et al. 1987, Day and Cooper 1995, Ainley et al. 1995, 1997b, Day et al. 2003b). These birds also nest on Hawaii (Reynolds and Richotte 1997, Reynolds et al. 1997, Day et al. 2003a), almost certainly nest on Molokai (Pratt 1988, Day and Cooper 2002), and may still nest on Oahu (Sincock and Swedberg 1969, Banko 1980b, Conant 1980, Pyle 1983; but see Ainley et al. 1997b). On Kauai, this species is known to nest at several inland locations, often on steep slopes vegetated by uluhe fern (*Dicranopteris linearis*) undergrowth and scattered ohia trees (*Metrosideros polymorpha*).

This study occurred during the incubation period (summer 2008) and the fledging period (fall 2007) of both species of interest (Telfer et al. 1987, Ainley et al. 1997b, Simons and Hodges 1998). There is interest in studying these species because of concerns about collisions with met towers and wind turbines. To date, however, there is a documented mortality of one Hawaiian Petrel and zero Newell's Shearwaters at wind turbines and none of either species at met towers (G. Spencer, FirstWind, Maui, HI, pers. comm.). (Note, however, that fatality studies for these species in the Hawaiian Islands have been conducted for only ~2.75 yr at one windfarm and six met towers.) In contrast, there has been a long history of petrel and shearwater mortality due to collisions with other human-made objects (e.g., powerlines) on Kauai (Telfer et al. 1987, Cooper and Day 1998, Podolsky et al. 1998) and Maui (Hodges 1992).

HAWAIIAN HOARY BATS

The Hawaiian Hoary Bat (*Lasiurus cinereus semotus*; 'Ope'ape'a) is the only terrestrial mammal native to Hawaii. It apparently is classified as endangered primarily because so little is known about its status and population trends. It is a nocturnal species that roosts solitarily during the daytime and occupies a wide variety of habitats, from sea level to >13,000 ft (Baldwin 1950, Fujioka and Gon 1988, Fullard 1989, David 2002). It occurs on all of the Main Hawaiian Islands (Baldwin 1950, van Riper and van Riper 1982, Tomich 1986, Fullard 1989, Kepler and Scott 1990, Hawaii Heritage Program 1991, David 2002; Day and Cooper, unpubl. data), although there is recent speculation that the species has disappeared from both Oahu and Molokai (State of Hawaii 2005).

Recent studies on mountaintops in the eastern US and on the prairies in both the US and Canada indicate that substantial kills of bats, including Hoary Bats, sometimes occur at windfarms (Arnett 2005, Erickson 2004, Kerns 2004, Barclay et al. 2007, Kunz et al. 2007b, Arnett et al. 2008). These fatalities have prompted researchers to develop standardized methods for assessing the use of proposed wind-energy projects by bats (Reynolds 2006, Kunz et al. 2007a). Most of the bat fatalities documented at wind farms have been of migratory tree-roosting species, including Hoary (*Lasiurus cinereus*), Eastern red (*Lasiurus borealis*), Big brown (*Eptesicus fuscus*), and Silver-haired (*Lasionycteris noctivagans*) bats, during seasonal periods of dispersal and migration in late summer and fall. Several hypotheses have been posited to explain these turbine interactions (e.g., Arnett 2005, Barclay et al. 2007, Cryan and Brown 2007, Kunz et al. 2007b, Cryan 2008), although none have been tested yet. Larkin (2006) suggested that bats may be killed when flying straight into objects without reacting, so their fatality rates may be correlated with their movement rates or foraging activity near windfarms; however, recent research by Baerwald et al. (2008) indicates that barotrauma (high-pressure damage to mammalian lungs) is a major cause of the fatalities. Because of these recent fatalities of migratory Hoary Bats at windfarms on the US mainland, there was interest in having us collect visual data on Hawaiian Hoary Bats during this study, even though the Hawaiian subspecies is non-migratory.

STUDY AREA

The proposed windfarm is located near the town of Kahuku, which is located near the northern tip of Oahu Island (Figures 1 and 2). Subsequent to our fall 2007 surveys, three 60-m-high meteorological (met) towers that are anchored by six guy wires in each of four directions were installed at the proposed windfarm. All guy wires are marked by bird flight-diverters (BFDs) with an orange aircraft-marker ball near the top of the uppermost guy wire and 17 spiral vibration dampers (Preformed Products, Cleveland, OH) total per anchor point. In addition, the current development plan for this site is to install 12 Clipper C-96 (“Clipper Liberty”) wind turbines. Each turbine would have a generating capacity of ~2.5 MW, for a total installed capacity of ~30 MW for the windfarm as a whole. The currently-proposed monopole towers would be ~80 m in height, and each turbine would have 3 rotor blades ~48 m long; hence, the total maximal height of a turbine would be ~128 m with a blade in the top-vertical position.

The proposed windfarm will be located on a low ridge that is oriented in a roughly east–west axis and that lies north of the northern end of the Koolau Range, which in turn lies just inland from the eastern shore of Oahu. The study site has an elevation varying from ~30 m to ~100 m above sea level and is extremely disturbed, being covered with old pasturelands and introduced species such as haole koa (*Leucaena leucocephala*), kiawe (*Prosopis pallida*), and christmasberry (*Schinus terebinthefolius*). Native vegetation such as ohia lehua trees (*Metrosideros polymorpha*) and uluhe (*Dicranopterus linearis*) ferns, which are the preferred nesting habitat for Newell's Shearwaters (Sincock and Swedberg 1969, Ainley et al. 1997b), occurs inland on the steeper slopes of the nearby Koolau Range (Day, photographs taken July 2008).

We conducted standard radar and audiovisual sampling at a site just northwest of the proposed windfarm and where there was a good view over the entire windfarm study area. This site was located on a rise in a pasture near an old WWII

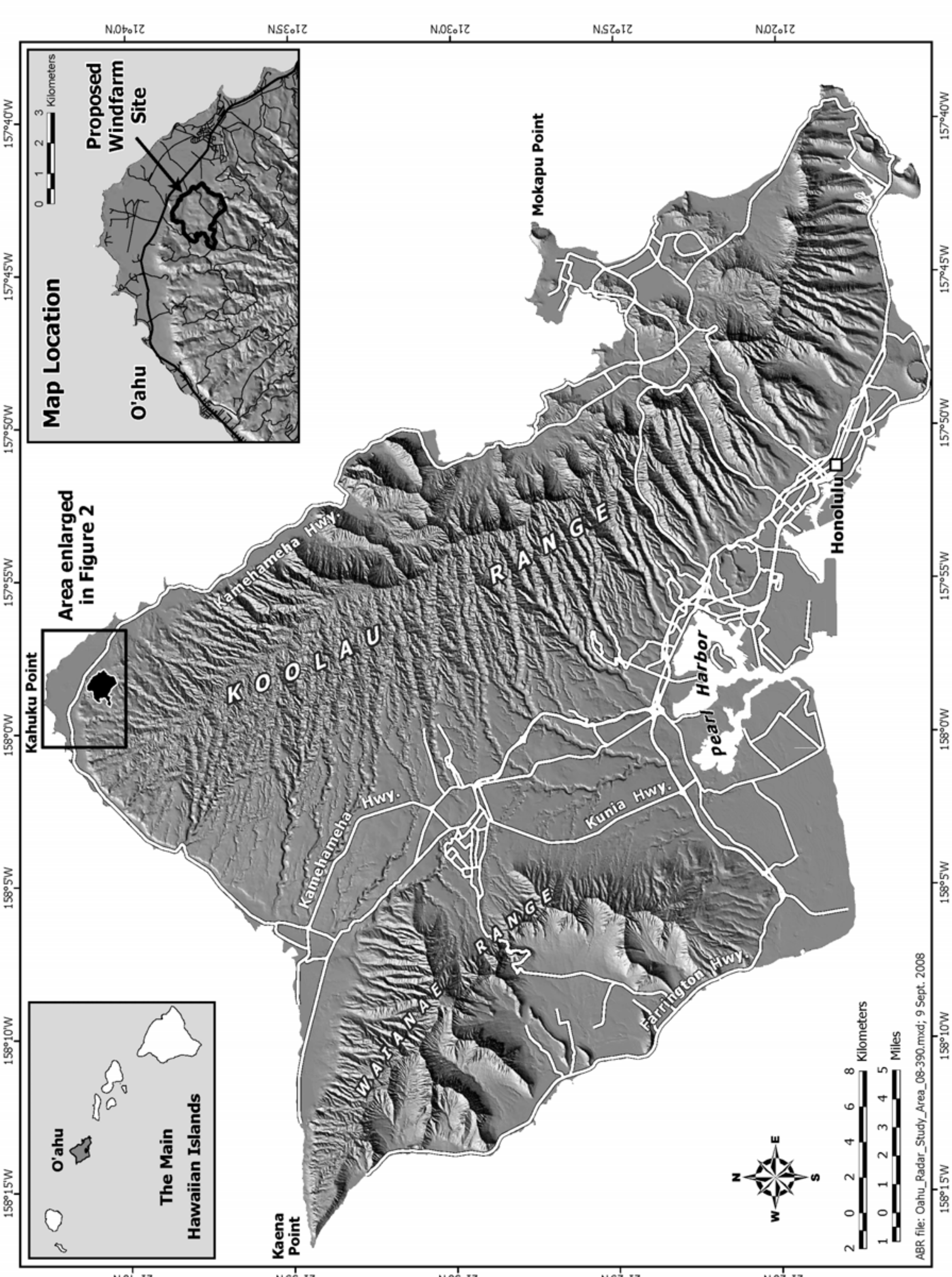

Figure 1. Oahu Island, Hawaii, showing the approximate location of the proposed windfarm study site.

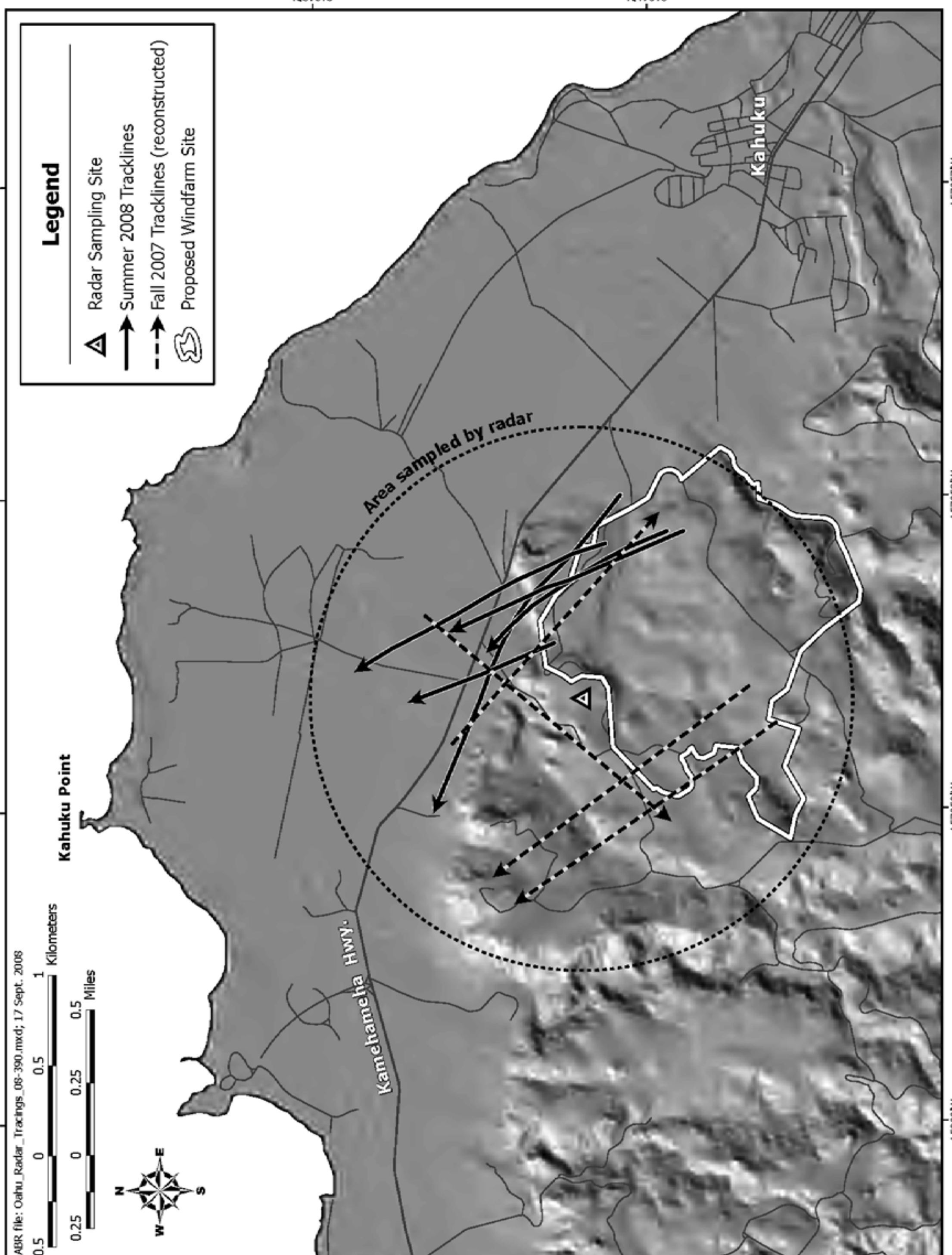

Figure 2. Location of proposed windfarm site and flight tracklines of probable petrel/shearwater targets recorded on radar, fall 2007 and summer 2008. Arrowheads indicate flight directions. Fall 2007 tracklines had to be reconstructed because the original tracings were lost.

gun-emplacement (21.68695°N 157.97745°W; WGS84 datum), provided good radar coverage with essentially no radar-shadow zones or extensive areas of ground-clutter within the study area, and was an excellent site for audiovisual sampling. The radar site was located at ~70 m elevation.

METHODS

DATA COLLECTION

Two observers monitored movements of birds and bats during 16–20 October 2007 and 1–8 July 2008 (Table 1) by following standard ornithological radar and audiovisual techniques used in previous studies (e.g., Cooper and Day 1995, 2003; Day and Cooper 1995, Day et al. 2003b). We collected data on five evenings (1800–2100) in the fall of 2007 and on 7 evenings (1900–2200) and mornings (0400–0600) over 8 days in the summer of 2008. One observer operated the radar, while the second observer conducted audiovisual sampling. For the purposes of this study, an evening and the following morning (i.e., from sunset to sunrise) were considered as occurring on the same date to simplify analytical results for each period of darkness.

Before each radar and audiovisual sampling period, we recorded standardized weather and environmental data: wind direction (to the nearest 5°, plus variable winds and no wind), wind speed (to the nearest 1 m/sec), percent cloud cover (to the nearest 5%), cloud ceiling height above ground level (agl; in several height categories), visibility (maximal distance we could see, in categories), light condition (daylight, crepuscular, or nocturnal, and with or without precipitation), precipitation type, and moon phase/position (lunar phase and whether the moon was above or below the horizon in the night sky).

RADAR SAMPLING

Our radar laboratory consisted of a marine radar that was mounted on the roof of an SUV vehicle. During all sampling, the antenna was positioned in the horizontal position (i.e., in surveillance mode), so the radar scanned the area surrounding the vehicle for movement rates, flight directions, flight behaviors, and groundspeeds of targets. A description of a similar radar laboratory can be found in Gauthreaux (1985a, 1985b), Cooper et al. (1991), and Mabee et al. (2006).

The radar used for this study was a Furuno Model 1510 X-band radar transmitting at 9.410 GHz through a slotted wave guide with a peak power output of 12 kW. We operated the radar at a 1.5-km range setting and a pulse-length of 0.07 μsec. The surveillance radar's antenna face was tilted upward by ~10–15°. Figure 3 shows the approximate sampling airspace for the Furuno FR–1510 marine radar at a 1.5-km range setting, as determined by field trials with Rock Pigeons (*Columba livia*).

Whenever energy is reflected from the ground, surrounding vegetation, and other objects that surround the radar unit, a ground-clutter echo appears on the radar's display screen. Because ground clutter can obscure targets of interest (i.e., birds and bats), we attempted to minimize it by picking optimal sampling locations. Ground clutter was minor at the study site and, in our opinion, did not cause us to miss any targets. Radar coverage also can be affected by shadow zones, which are areas of the screen where birds were likely to be flying at an altitude that would put them behind a hill or row of vegetation, so that they could not be detected. Shadow zones were minimal at the Kahuku site, and we do not believe that petrels or shearwaters could have crossed the radar screen without being detected by the radar.

We sampled during the evening and morning peaks of movement, which is when petrels and shearwaters fly inland toward the nesting colonies and seaward from the nesting colonies (Day and Cooper 1995). Thus, we conducted six 25-min counts of birds during the period 1800–2100 each night in the fall of 2007 and the periods 1900–2200 h and 0400–0600 in the summer of 2008 (Table 1). Each 25-min sampling period was separated by a 5-min break for collecting data on weather between sampling periods. To eliminate species other than those of interest (e.g., slowly-flying birds, insects), we recorded data only for those targets flying with an airspeed ≥30 mi/h (≥50 km/h). For each radar target, we recorded the time, number of radar targets, transect crossed (the four cardinal points—000°, 090°, 180°, or 270°; used in reconstructing flight paths), flight direction (to the nearest 1°), tangential range (the minimal distance

Table 1. Radar and audiovisual sampling effort at the proposed wind-energy site on Oahu Island, Hawaii, during fall 2007 and summer 2008.

	Sampling type	
Season/date	Surveillance radar	Audiovisual
FALL		
16 October	1800–2100	1800–2100
17 October	1800–2100	1800–2100
18 October	1800–2100	1800–2100
19 October	1800–2100	1800–2100
20 October	1800–1930 [a]	1800–1930 [a]
SUMMER		
1 July	–	1900–2200, 0400–0600
2 July	1900–2200, 0400–0600	1900–2200, 0400–0600
3 July	1900–2200, 0400–0600 [b]	1900–2200, 0400–0600
4 July	1900–2200 [b], 0400–0600 [b]	1900–2200, 0400–0600
5 July	1900–2200, 0400–0600	1900–2200, 0400–0600
6 July	1900–2200, 0400–0600	1900–2200, 0400–0600
7 July	1900–2200, 0400–0600	1900–2200, 0400–0600
8 July	1900–2200, 0400–0600	–

[a] Sampling stopped early because of battery problems.
[b] Some sampling time was lost because of rain.

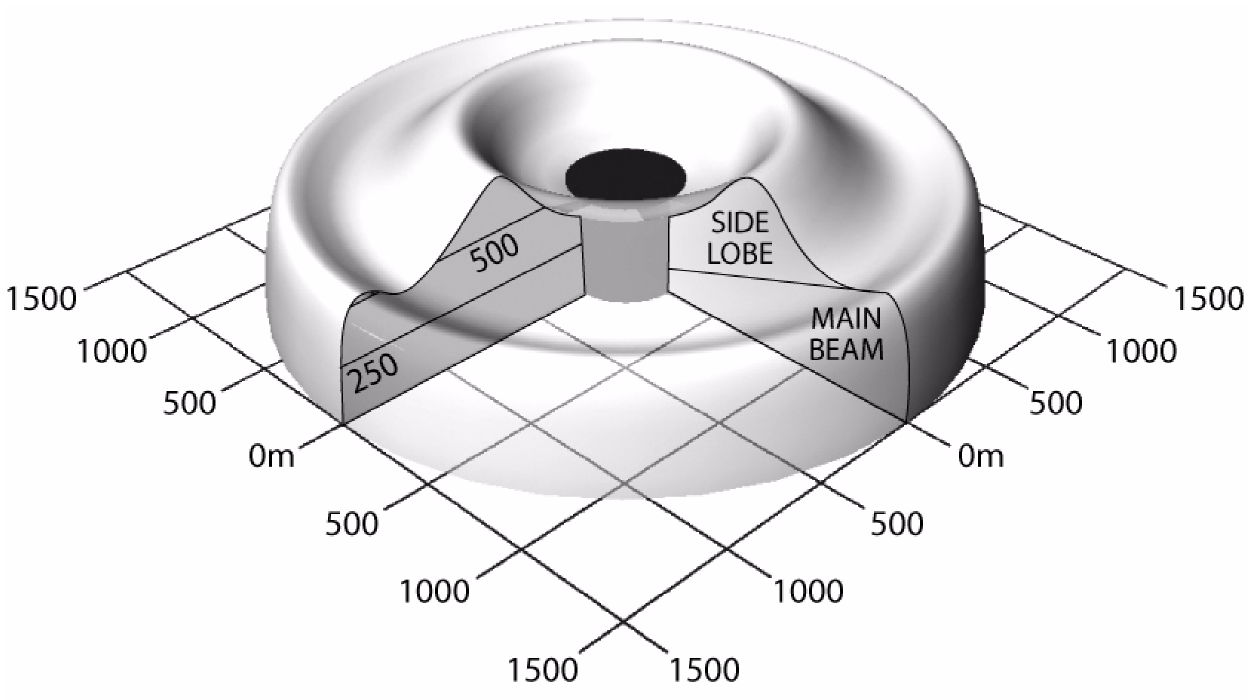

Figure 3. Approximate sampling airspace for the Furuno FR–1510 marine radar at the 1.5-km range setting, as determined by field trials with Rock Pigeons. Note that the configuration of the radar beam within 250 m of the origin was not determined.

to the target when it passed closest to the lab; also used in reconstructing actual flight paths, if necessary), flight behavior (straight, erratic, circling), velocity (to the nearest 5 mi/h [8 km/h]) species (if known), and number of birds or bats (if known).

AUDIOVISUAL SAMPLING

We also conducted audiovisual sampling for birds and bats concurrently with the radar sampling, to help identify targets observed on radar and to obtain flight-altitude information. During this sampling, we used 10× binoculars during crepuscular periods and used PVS-7 night-vision goggles during nocturnal periods to look for targets that were detected on the radar. The magnification of these Generation-3 goggles was 1×, and their performance was enhanced with the use of a 3-million-Cp floodlight that was fitted with an IR filter to avoid blinding and/or attracting these nocturnal birds. For each bird or bat seen during night-vision sampling, we recorded the time, species (to the lowest practical taxonomic unit—e.g., Newell's Shearwater, unidentified shearwater/petrel), number of birds or bats in the target, flight direction (the eight ordinal points), flight behavior (as above), flight altitude (m above ground level), and cardinal transect crossed (as above).

DATA ANALYSIS

RADAR DATA

We entered all data into a Microsoft Excel database. Data files were checked visually for errors after each night's sampling and were checked again electronically for errors prior to data analyses. All data summaries and analyses were conducted with the statistical software available in Microsoft Excel. For quality assurance, we cross-checked results of the Excel analyses with hand-tabulations of small subsets of data whenever possible.

Prior to analyses, radar data were filtered to remove non-target species. Only known petrel/shearwater targets or unknown targets with appropriate characteristics (i.e., with appropriate target size, flight characteristics, and airspeeds ≥30 mi/h) were included in data analyses of movement rates, flight directions, and flight behavior; all other species were excluded from those analyses. Following Mabee et al. (2006), we computed the airspeed (i.e., groundspeed corrected for wind speed and relative direction) of surveillance-radar targets with the formula:

$$V_a = \sqrt{V_g{}^2 + V_w{}^2 - 2V_gV_w\cos\theta},$$

where V_a = airspeed, V_g = target groundspeed (as determined from the radar's flight trackline), V_w = wind velocity, and θ is the angular difference between the observed flight direction and the direction of the wind vector.

We tallied counts of targets recorded during each sampling session, then converted the counts to estimates of movement rates (targets/h), based on the number of minutes sampled in each session. Battery problems can prevent sampling, and rain showers sometimes can obscure significant portions of the screen for several minutes at a time. Hence, periods when we were unable to sample for the full session were subtracted from the standardized 25-min sampling period, with the resulting number of minutes being used to calculate movement rates. We lost 11 min in 2 sampling sessions, plus 3 entire sampling sessions (all on the same evening), in the fall of 2007 because of battery problems and lost 16 min in 3 sampling sessions (all on different nights) because of rain in the summer of 2008 (Table 1).

We used the estimated movement rates on radar for each sampling period to calculate the mean ± 1 standard error (SE) movement rate at each site on each evening, morning, and overall for each date. Only known petrel/shearwater targets or unknown targets with appropriate sizes, flight characteristics, and groundspeeds (i.e., ≥30 mi/h) were included in data analyses of movement rates, flight direction, and flight behavior; all other species were excluded from these analyses.

We calculated the mean ± circular standard deviation (S') and the vector length (r) of the flight direction for all targets seen on radar. (The circular standard deviation is a statistical equivalent of the standard deviation that is used for directional data, and the vector length is a measure of how consistently the targets are moving in one direction.) We also classified general flight directions of each radar target as inland, seaward, or "other" and summarized these directional categories by site and by night. Because the shoreline in this area goes to a point at the northern tip of the island, we were unable to use normal methods to determine whether a target was flying inland or seaward. Instead, we defined an inland flight direction as 120–239°, a seaward flight direction as 300–059°, and an "other" flight direction as 060–119° or 240–299°. Finally, we plotted all tracklines on a map of the study area.

EXPOSURE AND FATALITY RATES

The risk-assessment technique that we have developed uses the radar data on seasonal movement rates to estimate numbers of birds flying over the area of interest (sampling site) across the portion of the year when birds are present on land. The model then uses information on the physical characteristics of the met towers and wind turbines to estimate horizontal-interaction probabilities, uses flight-altitude data and information on the height of the met towers and wind turbines to estimate vertical-interaction probabilities, and combines these interaction probabilities with the movement rates to generate annual exposure rates. These exposure rates represent the estimated numbers of petrels or shearwaters that pass within the airspace occupied by a met tower and its associated guy wires (or a wind turbine) each year. We then combine these exposure rates with (1) the probability that an exposure results in a fatality; and (2) the probability that birds detect structures and avoid interacting with them, to estimate fatality rates at each of the met towers in an average year.

Exposure Rates

We calculate an exposure rate by multiplying the annual movement rate by horizontal- and vertical-interaction probabilities. The movement rate is an estimate of the average number of birds passing in the vicinity of the proposed towers in a year, as indicated by the number of targets crossing the radar screen and the mean flock size/target. It is generated from the radar data by: (1) multiplying the average movement rates for summer and fall seasons by 5.5 h to estimate the number of targets moving over the radar site during those periods; (2) adjusting the sum of those counts to account for the estimated percentage of movement that occurs during the middle of the night (12.6%; Cooper and Day, unpubl. data); (3) multiplying that total number of targets/night by the mean number of Newell's Shearwaters/target (1.03 ± SE 0.01 Newell's Shearwaters/flock; *n* = 722 flocks; Day and Cooper, unpubl. data) to generate an estimate of the number of shearwaters passing in the vicinity of the proposed tower during an average night; and (4) multiplying those numbers by the number of days that these birds were exposed to risk in each season (150 days in the spring/summer and 60 days in the fall; Ainley et al. 1997b). (We believe that all of the targets we recorded were those of Newell's Shearwaters; see Results and Discussion.)

Interaction probabilities consist of both horizontal and vertical components. Please note that our horizontal and vertical interaction "probabilities" actually are just fractions of sampled airspace occupied by structures, rather than usual statistical probabilities. Hence, we assume that the probability of exposure is equal to the fraction of sampled air space that was occupied by a met tower or wind turbine and that there is a uniform distribution of birds in the sampled airspace.

The horizontal-interaction probability is the probability that a bird seen on radar will pass over the two-dimensional space (as viewed from the side) occupied by a met tower or wind turbine located somewhere on the radar screen. This probability is calculated from information on the two-dimensional area (side view) of the met tower or wind turbine and the two-dimensional area sampled by the radar screen. The met-tower system has a central tower with four sets of guy wires attached at six heights; hence, from a side view, the met-tower/guy-wire system appears from the side to be an isosceles triangle 60 m high with a base of 100 m and a side-view area of 3,000 m^2. The wind-turbine system will have a maximal height of 128 m, a radius of 48 m, and minimal (side-view) and maximal (front-view) areas of 768 m^2 and 7, 430 m^2, respectively. The ensuing ratio of the cross-sectional area of the met tower or wind turbine to the cross-sectional area sampled by the radar (3-km diameter times the height of the structure) indicates the probability of interacting with (i.e., flying over the airspace occupied by) the met tower or wind turbine.

The vertical-interaction probability is the probability that a bird seen on radar will be flying at an altitude low enough that it actually might pass through the airspace occupied by a met tower or wind turbine located somewhere on the radar screen. This probability is calculated from data on flight altitudes and from information on the towers' and proposed turbines' heights. We calculated the percentage of shearwaters with flight altitudes ≤60 m agl (maximal height of the met towers) and the percentage of shearwaters with flight altitudes ≤130 m agl (maximal height of the rotor-swept area on a proposed turbine). We used data on flight altitudes of Newell's Shearwaters from throughout the Hawaiian Islands (*n* = 688 birds; Day and Cooper, unpubl. data) to calculate the percentage of shearwaters with flight altitudes at or below the maximal height of the met towers (28.5%) or turbines (64.1%). We would have preferred to use flight-altitude data from Oahu for the flight-altitude percentage calculation, but we did not have any data from that island.

Fatality Rates

The annual fatality rate is calculated as the product of: (1) the exposure rate (i.e., the number of birds that might fly in the airspace occupied by a met tower or wind turbine); (2) the fatality probability (i.e., the probability of a fatal collision with a portion of the structure while in that airspace); and (3) the probability that a bird actually will detect and avoid entering the airspace containing the structure. The annual fatality rate is generated as an estimate of the number of birds killed/year as a result of collisions with the tower/turbine, based on a 210-d breeding season for Newell's Shearwaters (Ainley et al. 1997b). Because collision-avoidance probabilities are largely unknown, we present fatality estimates for a range of probabilities by these birds by assuming that 50%, 95%, or 99% of all shearwaters flying near a met tower or wind turbine will see and avoid it.

The estimate of the fatality-probability portion of the fatality-rate formula is derived as the product of: (1) the probability of colliding with the tower/guy wires or the proposed wind turbine if the bird enters the airspace occupied by either of these structures (i.e., are there gaps big enough for birds to fly through the structure without hitting any part of it?); and (2) the probability of dying if it collides with the met-tower frame/guy wires or the wind-turbine structure (including blades). The former probability is needed because the estimates of horizontal-interaction probability are calculated as if the met tower/guy wires and the wind turbine are solid structures. Because a bird hitting the met-tower frame/guy wires or wind turbine will have a high probability of actually dying unless it just brushes the structure with a wingtip, we used an estimate of 95% for the first fatality-probability parameter. The second probability (i.e., that of striking the structure) needs to be calculated differently for met towers and wind turbines. In the met-tower design, the tower frame is a solid monopole tower, and the four sets of guy wires at six heights each occupy a substantial proportion of the total cone of airspace enclosed by the tower and guy wires, making it a low probability that a bird could fly though the space occupied by this tower/guy wires without hitting some part of it. Hence, we conservatively estimated the probability of hitting a met tower or guy wires if the bird enters the airspace at 100%. Similarly, a bird approaching a wind turbine from the side has essentially a 100% probability of hitting the tower or a turbine blade. In contrast, a bird approaching from the back or front of a turbine may pass through the rotor-swept area without colliding with a blade, depending on the bird's size and speed of flight and the maximal rate of rotation of the turbine blades. We calculated the probability of collision for the “frontal” bird approach based upon the length of a shearwater (33 cm; Pratt et al. 1987); the average groundspeed of Newell's Shearwaters on the Hawaiian Islands (mean velocity = 36.4 mi/h [58.6 km/h]; *n* = 28 identified shearwater targets; Day and Cooper, unpubl. data) and the time that it would take a 33-cm-long shearwater to travel completely through a 2-m-wide turbine blade spinning at its maximal rotor speed (15.5 revolutions/min for this model); also see Tucker (1996). These calculations indicated that up to 15.6% of the disk of the rotor-swept area would be occupied by a blade sometime during the length of time (0.14 sec) that it would take a shearwater to fly completely past a rotor blade (i.e., to fly 2.33 m).

RESULTS

SURVEILLANCE-RADAR OBSERVATIONS

We recorded 3 targets on radar that fit our criteria for petrel/shearwater targets during the 5 nights of surveillance radar sampling in fall 2007 and recorded 5 targets on radar that fit our criteria for petrel/shearwater targets during the 8 nights of surveillance radar sampling in summer 2008 (Table 2). In addition, we recorded 1 target off-survey in fall 2007 that we discuss whenever possible here, to help increase our understanding of movements through the area. Movement rates of shearwater and petrel targets varied between 0 and 0.8 targets/h for individual sampling sessions and averaged 0.3 ± 0.2 targets/h overall in fall 2007 and 0.2 ± 0.1 targets/h overall in summer 2008 (Table 2). Mean movement rates generally were similar among nights, ranging from 0 to 0.8 targets/h among nights in fall 2007 and from 0 to 0.5 targets/h in summer 2008.

We recorded similar numbers of landward- and seaward-flying targets in fall 2007 (includes the 1 seaward-flying target seen off-survey on the evening of 18 October) but recorded only seaward-flying targets during both the evening and the morning in summer 2008 (Table 2). Overall 77.8% (including the target seen off-survey) of all targets were flying seaward, whereas 22.2% were flying landward.

Mean overall flight directions (± *S'*) were 323 ± 57° (*r* = 0.610; *n* = 9 targets, including one seaward-flying target seen off-survey on the evening of 18 October.) Mean evening flight directions were 316 ± 67° (*r* = 0.509; *n* = 7 targets). Six of the seven evening targets were strongly aligned along a southeast–northwest axis (142°, 301°, 322°, 335°, 343°, and 346°), whereas the remaining target was flying inland toward the southwest (220°); consequently, the vector length (*r*) was only moderate. Mean morning flight directions were 336 ± 1° (*r* = 0.999; *n* = 2 targets), with both targets being strongly aligned along the same southeast–northwest axis (335°, 337°); the extremely high *r* reflects this strong consistency of flight directions. Mean inland flight directions were 181 ± 41° (*r* = 0.777; *n* = 2 targets), with the moderate *S'* and *r* reflecting the almost-perfect balance of targets flying toward the southeast and the southwest. In contrast, mean seaward flight directions were 331 ± 14° (*r* = 0.970; *n* = 7 targets), with the small *S'* and the large *r* reflecting the great consistency of flight directions between 301° and 346°.

A qualitative assessment of flight paths and trajectories suggested that there was one pattern of movement in the area: a southeast–northwest axis of ~145–325° between the ocean and the northeastern end of the Koolau Range (8 targets). In addition, there was an outlier data point represented by a southwesterly flight toward the northern extremity of the Koolau Range or the valley between the Koolau and Waianae ranges (1 target; Figure 2). Nearly all targets that were heading seaward crossed the proposed windfarm site itself, with only one skirting the northeastern boundary of the site. One of the two targets that were heading inland did not cross the site.

Mean evening flight velocities (corrected to airspeeds; ± SE) were 42.3 ± 3.3 mi/h (*n* = 7 targets) and ranged from 33 to 57 mi/h. Mean morning flight velocities were 46.0 ± 2.0 (*n* = 2 targets) and ranged from 44 to 48 mi/h. Mean inland flight velocities were 38.0 ± 1.0 (*n* = 2 targets) and ranged from 37 to 39 mi/h, whereas mean seaward flight velocities were 44.6 ± 3.2 (*n* = 7 targets) and ranged from 33 to 57 mi/h. Mean overall flight velocities were 43.1 ± 2.6 (*n* = 9 targets) and ranged from 33 to 57 mi/h.

The timing of movement of targets suggested that all of the targets were those of Newell's Shearwaters (Table 3). No evening targets were recorded during the first sampling session, which is when only Hawaiian Petrels fly, and only one was recorded during the second session, which is when Hawaiian Petrel numbers are tapering off and Newell's Shearwater numbers are increasing; all other targets were flying after the point of complete darkness (Day and Cooper 1995, Cooper and Day 2003). This latter target, however, was flying after it was completely dark (i.e., after the point of complete darkness), suggesting that it was a Newell's Shearwater and not a Hawaiian Petrel. In the morning, the two targets also were recorded while it was completely dark out. Hence, we believe that all of the targets recorded on radar were those of Newell's Shearwaters (Table 3).

No targets that we believed were petrels or shearwaters were observed flying in an erratic or

Table 2. Daily and overall counts and movement rates of seabirds detected on surveillance radar at the proposed wind-energy site on Oahu Island, Hawaii, during fall 2007 and summer 2008. Overall rates are presented as mean ± SE (*n* number of sampling sessions except for totals for a season, when they are number of nights).

		Number of targets			Movement rate (targets/h)		
Season/date	Time period	Landward	Seaward	Total	Landward	Seaward	Total
FALL							
16 October	Evening	1	1	2	0.4 ± 0.4 (6)	0.4 ± 0.4 (6)	0.8 ± 0.5 (6)
17 October	Evening	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
18 October [a]	Evening	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
19 October	Evening	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
20 October	Evening	1	0	1	0.8 ± 0.8 (3)	0.0 ± 0.0 (3)	0.8 ± 0.8 (3)
Total fall	Evening	2	1	3	0.2 ± 0.2 (5)	0.1 ± 0.1 (5)	0.3 ± 0.2 (5)
	Total	2	1	3	0.2 ± 0.2 (5)	0.1 ± 0.1 (5)	0.3 ± 0.2 (5)
SUMMER							
1 July	Morning	0	0	0	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)
	Total	0	0	0	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)
2 July	Evening	0	1	1	0.0 ± 0.0 (6)	0.4 ± 0.4 (6)	0.4 ± 0.4 (6)
	Morning	0	0	0	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)
	Total	0	1	1	0.0 ± 0.0 (10)	0.2 ± 0.2 (10)	0.2 ± 0.2 (10)
3 July	Evening	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
	Morning	0	0	0	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)
	Total	0	0	0	0.0 ± 0.0 (10)	0.0 ± 0.0 (10)	0.0 ± 0.0 (10)
4 July	Evening	0	1	1	0.0 ± 0.0 (6)	0.4 ± 0.4 (6)	0.4 ± 0.4 (6)
	Morning	0	1	1	0.0 ± 0.0 (4)	0.6 ± 0.6 (4)	0.6 ± 0.6 (4)
	Total	0	2	2	0.0 ± 0.0 (10)	0.5 ± 0.3 (10)	0.5 ± 0.3 (10)
5 July	Evening	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
	Morning	0	0	0	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)
	Total	0	0	0	0.0 ± 0.0 (10)	0.0 ± 0.0 (10)	0.0 ± 0.0 (10)
6 July	Evening	0	1	1	0.0 ± 0.0 (6)	0.4 ± 0.4 (6)	0.4 ± 0.4 (6)
	Morning	0	1	1	0.0 ± 0.0 (4)	0.6 ± 0.6 (4)	0.6 ± 0.6 (4)
	Total	0	2	2	0.0 ± 0.0 (10)	0.5 ± 0.3 (10)	0.5 ± 0.3 (10)

Table 2. Continued.

Season/date	Time period	Number of targets			Movement rate (targets/h)		
		Landward	Seaward	Total	Landward	Seaward	Total
7 July	Evening	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
	Morning	0	0	0	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)	0.0 ± 0.0 (4)
	Total	0	0	0	0.0 ± 0.0 (10)	0.0 ± 0.0 (10)	0.0 ± 0.0 (10)
8 July	Evening	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
	Total	0	0	0	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (6)
Total summer	Evening	0	3	3	0.0 ± 0.0 (7)	0.2 ± 0.1 (7)	0.2 ± 0.1 (7)
	Morning	0	2	2	0.0 ± 0.0 (7)	0.2 ± 0.1 (7)	0.2 ± 0.1 (7)
	Total	0	5	5	0.0 ± 0.0 (7)	0.2 ± 0.1 (7)	0.2 ± 0.1 (7)

[a] In addition, a petrel/shearwater-like target was recorded flying seaward at 1930 during a break between sampling sessions (i.e., off-sampling).

Table 3. Evening timing of movement of bird targets on ornithological radar, with mean movement rates and percentages of nightly movements observed by half-hour period at the proposed wind-energy site on Oahu Island, Hawaii, during fall 2007 and summer 2008.

Time period/time	Number of targets	Percent
EVENING		
1800–1829	0	0
1830–1859	1	16.7
1900–1929	1	16.7
1930–1959	2	33.3
2000–2029	0	0
2030–2059	2	33.3
MORNING		
0400–0429	0	0
0430–0459	0	0
0500–0529	2	100.0
0530–0559	0	0

circling manner. Straight-line flights composed 100% of all flights.

AUDIOVISUAL OBSERVATIONS

We visually recorded no Hawaiian Petrels, no Newell's Shearwaters, no unidentified shearwaters/petrels, and no Hoary Bats during our 5 nights of audiovisual sampling in fall 2007 (Table 4). We visually recorded no Hawaiian Petrels, no Newell's Shearwaters, no unidentified shearwaters/petrels, and 1 Hoary Bat during our 7 nights and 7 mornings of audiovisual sampling in summer 2008. Other species of interest that we recorded audiovisually included Pacific Golden-Plovers, Short-eared Owls, Barn Owls, "Koloa-like" Ducks (i.e., Koloa Ducks that may or may not have hybridized with Mallards), unidentified ducks, and Cattle Egrets. Cattle Egrets, in particular, were common in the area and moved *en masse* toward nocturnal roosting grounds every evening between sunset and darkness and from roosting grounds to feed in the study area in the morning; they only were diurnal in activity.

We recorded 1 Hoary Bat during audiovisual surveys, on the evening of 6 July 2008 (Table 4), translating to an estimated occurrence rate of 1 bat in 97 25-min observation sessions (0.0004 bats/h). It was flying slowly in a seaward direction from farther inland at an altitude of ~35 m agl. Many moths were active that night, although the reason why was unclear: winds were from a similar direction (~100°, or just south of east) and at a wind speed (~4 mi/h [~6 km/h]) similar to wind conditions on other nights. Although we did not record them audiovisually, we also recorded bat-like targets on radar on several nights over the marshy flats to the north of us.

EXPOSURE RATES

The exposure rate is calculated as the product of three variables: annual movement rate, horizontal-interaction probability, and vertical-interaction probability (Tables 5 and 6). As such, it is an estimate of the number of birds flying in the vicinity of a met tower or a wind turbine (i.e., crossing the radar screen) that could fly in a horizontal location and at a low-enough altitude that they could interact with a tower nor turbine. In this modeling exercise, we used the radar-based movement data collected during October 2007 and July 2008 as model inputs; data on the timing of movements at the study site to determine proportions of Hawaiian Petrels and Newell's Shearwaters; data on the timing of movements from Day and Cooper (1995) to determine the proportion of birds flying during the off-peak hours in the middle of the night that we did not sample in this study; information on the mean flock size of targets of each species (Day and Cooper, unpubl.

Table 4. Number of Hawaiian Petrels (HAPE), Newell's Shearwater (NESH), unidentified shearwater/petrels (UNSP), and Hawaiian Hoary Bats (HOBA) recorded during audiovisual surveys at the proposed wind-energy site on Oahu Island, Hawaii, during fall 2007 and summer 2008. *n* number of sampling sessions.

	Number				
Season/date (*n*)	HAPE	NESH	UNSP	HOBA	Other species [a]
FALL					
16 October (6)	0	0	0	0	1 BAOW; 10^+ CAEG
17 October (6)	0	0	0	0	10^+ CAEG
18 October (6)	0	0	0	0	10^+ CAEG
19 October (6)	0	0	0	0	1 BAOW; 10^+ CAEG
20 October (3)	0	0	0	0	10^+ CAEG
Total fall (27)	0	0	0	0	
SUMMER					
1 July (4)	0	0	0	0	2 PAGP; 10^+ CAEG
2 July (10)	0	0	0	0	1 SEOW; 1 KODU; 3 UNDU; 10^+ CAEG
3 July (10)	0	0	0	0	10^+ CAEG
4 July (10)	0	0	0	0	10^+ CAEG
5 July (10)	0	0	0	0	10^+ CAEG
6 July (10)	0	0	0	1	10^+ CAEG
7 July (10)	0	0	0	0	10^+ CAEG
8 July (6)	0	0	0	0	10^+ CAEG
Total summer (70)	0	0	0	1	
Total (97)	0	0	0	1	

[a] PGPL = Pacific Golden-Plover (*Pluvialis fulva*); SEOW = Short-eared Owl (*Asio flammeus*); BAOW = Barn Owl (*Tyto alba*); KODU = "Koloa-like" Duck (*Anas wyvilliana* or Koloa hybrid with Mallard *Anas platyrhynchos*); UNDU = unidentified duck CAEG = Cattle Egret (*Bubulcus ibis*).

data); and information on the dimensions of the met towers and proposed wind turbines to calculate annual movement rates of these birds through the study area. By using these parameters, we estimate that 0 Hawaiian Petrels and 307 Newell's Shearwaters pass over the 1.5-km-radius radar sampling area (Figure 2) during an average year (Tables 5 and 6).

To generate annual exposure rates of birds exposed to each met tower (birds/tower/yr) or wind turbine (birds/turbine/yr), we then multiplied the annual movement rate by the horizontal-interaction probability and the vertical-interaction probability. For the horizontal-interaction probability, we estimated that it was 0.01667 at a 60-m met tower (Table 5) and that it ranged between 0.00200 and 0.01935, depending on whether the bird was approaching the wind turbine from the side or the front, respectively (Table 6). We were unable to detect any petrels or shearwaters visually in this study, so, for the purposes of vertical-interaction probabilities in the model, we used flight-altitude data for Newell's Shearwaters from elsewhere in the Hawaiian Islands (*n* = 688 birds) to estimate that 28.5% of all birds passing through this area would be flying at or below met-tower height (Table 5) and that 64.1% of all birds passing through this area would be flying at or below turbine height (Table 6).

The annual exposure rate then is calculated by multiplying the annual movement rate by the horizontal-interaction probability and the vertical-interaction probability. By applying these proportions to our data, we estimate that 1.46 Newell's Shearwaters will fly within the space occupied by a met tower during an average year (Table 5) and that 0.39–3.81 Newell's Shearwaters will fly within the space occupied by a proposed

Table 5. Estimated average exposure rates and fatality rates of Newell's Shearwaters at guyed 60-m monopole met towers at the proposed wind-energy site on Oahu Island, Hawaii, based on radar data collected in October 2007 and July 2008. Values of particular importance are in boxes.

Variable/parameter for 60-m monopole met tower	Estimate
MOVEMENT RATE (MVR)	
A) Mean movement rate (targets/h)	
A1) Mean rate during nightly peak movement periods in spring/summer based on July 2008 data (targets/h)	0.2
A2) Mean rate during nightly peak movement periods in fall based on July 2008 data (targets/h)	0.3
B) Number of hours of evening and morning peak period sampling	5.5
C) Mean number of targets during evening and morning peak movement periods	
C1) Spring/summer (A1 * B)	1.100
C2) Fall (A2 * B)	1.650
D) Mean proportion of birds moving during off-peak hours of night	0.126
E) Seasonal movement rate (targets/night) = ((C * D) + C)	
E1) Spring/summer	1.24
E2) Fall	1.86
F) Mean number of birds/target	1.03
G) Estimated proportion that is Newell's Shearwaters	1.00
H) Daily movement rate (birds/day =E * F * G)	
H1) Spring/summer	1.28
H2) Fall	1.91
I) Fatality domain (days/year)	
I1) Spring/summer	150
I2) Fall	60
J) Annual movement rate (birds/year; = ((H1 * I1) + (H2 * I2)), rounded to next whole number)	307
HORIZONTAL-INTERACTION PROBABILITY (IPH)	
K) Maximal cross-sectional area of tower and guys (side view = ((50 m * 60 m)/2) *2 = 3,000 m^2	3,000
L) Cross-sectional sampling area of radar at or below 60 m tower height (= 3,000 m * 60 m = 180,000 m^2)	180,000
M) Horizontal-interaction probability (= K/L, rounded to 8 decimal places)	0.01666667
VERTICAL-INTERACTION PROBABILITY (IPV)	
N) Proportion of Newell's Shearwaters flying ≤ tower height in Hawaiian Islands (n = 688)	0.285
EXPOSURE RATE (ER = MVR*IPH*IPV)	
O) Daily exposure rate (birds/tower/day = H * M * N, rounded to 8 decimal places)	
O1) Spring/summer	0.00605738
O2) Fall	0.00908607
P) Annual exposure rate (birds/tower/year = J * M * N, rounded to 8 decimal places)	1.45765504
FATALITY PROBABILITY (MP)	
Q) Probability of striking tower or guys if in airspace	1.00
R) Probability of fatality if striking tower or guys	0.95
S) Probability of fatality if an interaction (= Q * R)	0.95000
FATALITY RATE (= ER*MP)	
T) Annual fatality rate with 50% exhibiting collision avoidance (birds/tower/year = P * S * 0.50)	0.69239
U) Annual fatality rate with 95% exhibiting collision avoidance (birds/tower/year = P * S* 0.05)	0.06924
V) Annual fatality rate with 99% exhibiting collision avoidance (birds/tower/year = P * S * 0.01)	0.01385

Table 6. Estimated average exposure rates and fatality rates of Newell's Shearwaters at Clipper C-96 wind turbines at the proposed wind-energy site on Oahu Island, Hawaii, based on radar data collected in October 2007 and July 2008. Values of particular importance are in boxes.

Variable/parameter for Clipper C-96 turbine	Estimate: Minimum	Estimate: Maximum
MOVEMENT RATE (MVR)		
A) Mean movement rate (targets/h)		
A1) Mean rate during nightly peak movement periods in spring/summer based on July 2008 data (targets/h)	0.2	0.2
A2) Mean rate during nightly peak movement periods in fall based on October 2007 data (targets/h)	0.3	0.3
B) Number of hours of evening and morning peak period of movement	5.5	5.5
C) Mean number of targets during evening and morning peak movement periods		
C1) Spring/summer (A1 * B)	1.100	1.100
C2) Fall (A2 * B)	1.650	1.650
D) Mean proportion of birds moving during off-peak hours of night	0.126	0.126
E) Seasonal movement rate (targets/night) = ((C * D) + C)		
E1) Spring/summer	1.24	1.24
E2) Fall	1.86	1.86
F) Mean number of birds/target	1.03	1.03
G) Estimated proportion that is Newell's Shearwaters	1.00	1.00
H) Daily movement rate (birds/day =E * F * G)		
H1) Spring/summer	1.28	1.28
H2) Fall	1.91	1.91
I) Fatality domain (days/year)		
I1) Spring/summer	150	150
I2) Fall	60	60
J) Annual movement rate (birds/year; = ((H1 * I1) + (H2 * I2)), rounded to next whole number)	307	307
HORIZONTAL-INTERACTION PROBABILITY (IPH)		
K) Turbine height (m)	128	128
L) Blade radius (m)	48	48
M) Height below blade (m)	32	32
N) Front to back width (m)	6	6
O) Min side profile area (m²) = (K * N)	768	
P) Max front profile area (m²) = (M * N) + (π x L²)		7,430
Q) Cross-sectional sampling area of radar at or below 128-m turbine height (= 3,000 m * 128 m = 384,000 m²)	384,000	384,000
R) Minimal horizontal-interaction probability (= O/Q, rounded to 8 decimal places)	0.00200000	
S) Maximal horizontal-interaction probability (= P/Q, rounded to 8 decimal places)		0.01934960
VERTICAL-INTERACTION PROBABILITY (IPV)		
T) Proportion of Newell's Shearwaters flying ≤ turbine height in Hawaiian Islands (*n* = 688)	0.641	0.641
EXPOSURE RATE (ER = MVR*IPH*IPV)		
U) Daily exposure rate (birds/turbine/day = H * (R or S) * T, rounded to 8 decimal places)		
O1) Spring/summer	0.00163549	0.01582306
O2) Fall	0.00245324	0.02373459
V) Annual exposure rate (birds/turbine/year = J * (R or S) * T, rounded to 8 decimal places	0.39356686	3.80768066
FATALITY PROBABILITY (MP)		
W) Probability of striking turbine if in airspace on a side approach	1.00	1.00
X) Probability of striking turbine if in airspace on frontal approach	0.151	0.151
Y) Probability of fatality if striking turbine	0.95	0.95
Z1) Probability of fatality if an interaction on side approach (= W * Y)	0.95000	
Z2) Probability of fatality if an interaction on frontal approach (= X * Y)		0.14345
FATALITY RATE (= ER*MP)		
Annual fatality rate with 50% exhibiting collision avoidance (birds/turbine/year = V * Z * 0.50)	0.18694	0.27311
Annual fatality rate with 95% exhibiting collision avoidance (birds/turbine/year = V * Z * 0.05)	0.01869	0.02731
Annual fatality rate with 99% exhibiting collision avoidance (birds/turbine/year = V * Z * 0.01)	0.00374	0.00546

wind turbine during an average year (Table 6). Note that these numbers are exposure rates and, thus, include an unknown proportion of birds that would detect and avoid the met towers or wind turbines. Hence, exposure rates estimate how many shearwaters/year would be exposed to met towers or wind turbines and do not necessarily estimate how many birds actually would collide with these structures.

FATALITY MODELING

Fatality estimates use two parameters to correct estimates of exposure rates to estimates of fatality rates. The first parameter involves the fatality probability that a bird flying through the airspace occupied by one of these structures will be fatally injured; for this exercise, we estimate it to be 95% for met towers and 14.8% and 95% for frontal approaches and side approaches to wind turbines, respectively. The second parameter involves correcting the subsequent number by the collision-avoidance probability, which is the proportion of these birds that do not collide with these structures because they detect and avoid them by flying around or over them.

Once collision-avoidance information is known, one may be able to assess the likelihood of avian fatalities at this proposed windfarm project with greater certainty. We speculate that the proportion of birds that detect and avoid met towers and wind turbines is substantial (see Discussion), but there are no shearwater-specific data available to use for an estimate of these factors for either marked-guyed met towers or wind turbines. Because it is necessary to calculate the annual fatality of shearwaters for the proposed project, however, we made some calculations to explore what level of magnitude the annual fatality rate might be. For the model, we assumed that 50%, 95%, or 99% of all birds will be able to detect and avoid the met towers and turbines. If we use those scenarios, the estimates of annual fatality would be 0.014–0.692 Newell's Shearwaters/met tower/year (Table 5) and 0.004–0.273 Newell's Shearwaters/wind turbine/year (Table 6). Fatality rates are higher for the met tower than the wind turbine because the extensive set of guy wires causes the met tower to have a larger three-dimensional size than the wind turbine; in addition, the fact that the turbine's rotor-swept area is not solid also allows birds to pass through it without colliding, again reducing fatality rates. We caution again, however, that these avoidance assumptions are not based on empirical data.

DISCUSSION

PETRELS AND SHEARWATERS

SPECIES COMPOSITION

Our radar data suggest that the radar targets that we recorded in 2007–2008 were those of Newell's Shearwaters, rather than Hawaiian Petrels or other species. The timing of movements entirely when it was completely dark and the inland–seaward directions of flight are similar to those for this species elsewhere in the Hawaiian Islands (Day and Cooper 1995, Cooper and Day 2003, Reynolds et al. 1997, Day et al. 2003a). In addition, we can find no records of Hawaiian Petrels on Oahu in the past 50–100 yr.

Other information suggesting that these targets were only of Newell's Shearwaters is that only Newell's Shearwaters have been recorded on Oahu in the past 50–100 yr, with a high probability of nesting in the Koolau Range. There are multiple records of Newell's Shearwaters in the Aiea area on 27 May 1954 (Richardson 1955) and 26 May and 2 and 5 June 1990 (Pyle 1990), and there are multiple records at the Honolulu Airport and in Honolulu itself on 7 August 1959 (Hatch 1959, cited in Banko 1980a); on 3 July 1961 (King and Gould 1967; Carpenter et al. 1962, cited in Banko 1980a); somewhere between 1973 and 1975 (Banko 1980a); and on 19 July 1985 (Pyle 1986). In addition, records of Newell's Shearwaters heard calling in the Waianae Mountains during the summer have been reported in recent years (G. Spencer, pers. comm.).

Importantly, there are numerous records of Newell's Shearwaters in the Koolau Range. For example, Newell's Shearwaters have been found dead at the tunnel on the Pali Highway on 4 August, 9 September, and 19, 25, and 27 November 1967 (Sincock and Swedberg 1969); on 26 May 1971 (Banko 1980a); on 4 September 1972 (Banko 1980a); on 18 July 1975 (Conant 1980); and on 9 August 2008 (2 birds <100 m from the tunnel entrance; Yukie and Tim Ohashi, Volcano, HI, in litt.). Shallenberger (1976, cited in Conant 1980) also reported seeing these birds flying at night over the Pali Highway in the 1970s, again suggesting nesting somewhere in the Koolau Mountains. In addition, a dead Newell's Shearwater was found on the beach near Laie Point on 8 June 1987 (Pyle 1987). The occurrence of these birds inland during both the summer breeding season and the fall fledging period suggests nesting somewhere in the Koolau Range.

An additional piece of information suggesting nesting by Newell's Shearwaters in the Koolau Range comes from the data collected in this study. All targets except one were heading into or out of the northeastern side of the Koolau Range, especially inland from the area between Kahuku and Laie. In this area, the mountains are steep (providing some protection from ground-based predators), and there are several patches of uluhe ferns on the steeper hillside in this area that are large enough to be visible from 1–2 mi (2–3 km) away. The consistent orientation of movements toward this area and the presence of both safe habitat (steep hillsides) and appropriate nesting habitat (uluhe ferns) suggest that at least one small Newell's Shearwater colony exists in this area.

MOVEMENT RATES

Our sampling dates occurred during the late-incubation period (summer) and the fledging period (fall) of Newell's Shearwaters (Ainley et al. 1997b). During the summer period, breeding adults, nonbreeding adults, and subadults are visiting the colonies; during the fall period, the activity is that of breeding adults and fledging young (Telfer et al. 1987; Ainley et al. 1997b). The average incubation shift is 10 days for Newell's Shearwaters (B. Zaun, USFWS Kauai National Wildlife Refuge Complex, Kilauea, HI, in litt.), so a breeding adult does not visit the nesting colony every night during incubation.

The overall mean evening movement rate of shearwaters at the proposed windfarm site was 0.2–0.3 targets/h for the two seasons. These data suggest that extremely low numbers of shearwaters are flying in the vicinity of this proposed windfarm site. Unfortunately, we have no other radar data from Oahu for comparison; however, data from almost all sampling sites on all other islands (e.g., Day and Cooper 1995, 2002; Cooper and Day 2003, Day et al. 2003a) are larger, and often much larger, than these movement rates.

The only data set from Oahu that is available for comparison is from Denis and Verschuyl (2007), who sampled 2–4 mi (3–6 km) inland from our sampling site in May 2007. During that 7-day study, they recorded 16 targets that they believed were those of Hawaiian Petrels or Newell's Shearwaters, resulting in an overall estimated mean movement rate of ~0.5 targets/h. There are several methodological differences between their study and ours, so we are unable to make a direct comparison between our results and the results of their study. First, they sampled during May, which is the period when Newell's Shearwaters make an egg-laying exodus from the colonies (Ainley et al. 1997b). As a result, one would have expected extremely low numbers of (if any) Newell's Shearwaters to have been visiting the colonies at that time. In addition, they used a minimal-cutoff flight speed (airspeed) of 40 mi/h (64 km/h), which we believe is too high for these species (Day and Cooper 1995, unpubl. data), resulting in an underestimation of the true movement rate. In addition, their mean flight directions (264° and 276° in the evening and morning, respectively) bear no resemblance to those recorded nearby in this study; and those flight directions suggest that their targets primarily were of birds of an unidentified species crossing over the northern side of the island, rather than entering and leaving colonies in an inbound/seaward pattern like Newell's Shearwaters would be expected to do. All of these factors lead us to suspect that they may have had significant contamination of their sample by Sooty Terns, tropicbirds, or other nocturnal seabirds.

FLIGHT ALTITUDES

We were unable to collect flight-altitude data on Newell's Shearwaters at the Kahuku study site. Consequently, for the modeling exercise, we used data from other locations in the Hawaiian Islands to estimate the percentage of birds that were flying low enough to be at risk of colliding with either a met tower or a wind turbine. The only data on flight altitudes of shearwater or petrel targets available from Oahu are those from Denis and Verschuyl (2007), who estimated a mean flight altitude (measured on vertical radar) of either 228 m agl (Executive Summary) or 260 m agl (Results); however, it was unclear how many targets this estimate incorporated. In addition, we have reservations about the movement-rate data in this study (see above) that also should be applied to the identity of targets in the flight-altitude data.

EXPOSURE AND FATALITY RATES

We estimate that 1.46 Newell's Shearwaters will fly within the space occupied by a met tower in an average year and that 0.39–3.81 Newell's Shearwaters will fly within the space occupied by a proposed wind turbine in an average year. We used these estimated exposure rates as a starting point for developing a complete avian risk assessment; however, we emphasize that it currently is not known whether bird use and fatality rates at windfarms are strongly correlated. For example, Cooper and Day (1998) found no relationship between movement rates and fatality rates of Hawaiian Petrels and Newell's Shearwaters at powerlines on Kauai. Hence, other factors (e.g., weather) could be more highly correlated with fatality rates than is bird abundance (as expressed through movement rates). To determine which factors are most relevant, future studies should collect concurrent data on movement rates, weather, and fatality rates to begin to determine whether movement rates and/or weather conditions can be used to predict the likelihood of shearwater fatalities at proposed met towers and windfarms.

COLLISION AVOIDANCE

In addition to these questions about the unknown relationships among abundance, weather, and fatality, few data are available on the proportion of shearwaters that do not collide with met towers or wind turbines because of collision-avoidance behavior (i.e., birds completely alter their flight paths horizontally and/or vertically to avoid flying through the space occupied by a wind turbine or met tower). Clearly, the detection of met towers, wind turbines, or other structures could result in collision-avoidance behavior by these birds and reduce the likelihood of collision. Unfortunately, Cooper and Day (1998) indicated that Newell's Shearwaters are not very maneuverable and fly only during nocturnal periods, suggesting that they may not have a good ability to avoid met towers or turbines.

Some collision-avoidance information is available on petrels and shearwaters from earlier work conducted on Kauai (Cooper and Day 1998; Day and Cooper, unpubl. data). Those data suggest that the behavioral-avoidance rate of Newell's Shearwaters near powerlines is high. For example, although we were unable to calculate an avoidance rate *per se* for the Kauai data, none (0%) of the 392 Newell's Shearwaters that passed within 150 m (vertical distance) of a powerline collided with it. These numbers probably include a substantial proportion of shearwaters that had flight paths that did not require a course correction to avoid the powerline; however, even when one examines only those shearwaters that flew within 25 m of a powerline (i.e., those at greatest risk of collision), 0 (0%) of 113 collided with the lines. Further, all 34 shearwaters that were observed reacting to the lines were able to avoid collision (i.e., a 100% collision-avoidance rate for that subset of birds if one assumes that, without avoidance, all of those birds would have collided with the lines).

Additional data that might provide some insight on collision-avoidance behavior of petrels and shearwaters are available from studies associated with the KWP I windfarm (20 turbines, 3 met towers) on Maui Island. One Hawaiian Petrel fatality and 0 Newell's Shearwater fatalities were recorded at that windfarm in the first 2.75 yr of operation (G. Spencer, pers. comm.). After correcting these apparent-fatality values with data for scavenging bias and searcher efficiency collected in the first year of study, UPC Wind Management (2007, 2008, unpubl. data) has calculated that the 1 observed fatality as of October 2008 equates to a corrected direct fatality of ~1.2 Hawaiian Petrels/yr and 0.0 Newell's Shearwaters/yr. Cooper and Day (2004b) also modeled seabird fatality rates for the KWP I windfarm, based on movement rates from radar studies there (Day and Cooper 1999; Cooper and Day 2004a, 2004b), and estimated that the combined annual fatality of Hawaiian Petrels and Newell's Shearwaters at the KWP I site would be ~3–18 birds/yr with a 50% avoidance rate, ~1–2 birds/yr with a 95% avoidance rate, and <1 bird/yr with a 99% avoidance rate. Thus, the fatality model using a 95% avoidance rate has been a much closer fit with the measured fatality rates than was the fatality model using a 50% avoidance rate or a 99% avoidance rate.

Comparable avoidance data are not available for the met towers, but the fact that no birds have been found killed at the 3 guyed met towers at the KWP I windfarm (i.e., at the 1 30-m tower and the 2 55-m towers) during the first 2.75 yr of operation also suggests that petrels and shearwaters have been avoiding those structures. In addition to the recent KWP information, a fatality study conducted at two ~40-m-high guyed met towers and four ~25-m-high guyed met towers at the KWP I site in May–July 1996 found no downed petrels or shearwaters on any of the 26 searches (Nishibayashi 1997), again suggesting avoidance of met towers.

In summary, the currently available data on Hawaiian Petrels and Newell's Shearwaters suggest that the avoidance rate of these birds at transmission lines and tall structures is high. Data from the fatality searches at met towers and wind turbines on Maui are more difficult to interpret because they suggest high avoidance—but they are not a direct measure of avoidance; however, those data suggest that the avoidance of those structures must be high because the estimated fatality rate is so low. Thus, the overall body of evidence, while incomplete, is consistent with the notion that the average avoidance rate of met towers and wind turbines is greater than 50% and is as high as 95% or more. The ability of Hawaiian Petrels and Newell's Shearwater to detect and avoid most objects under low-light conditions makes sense from a life-history standpoint, in that they forage extensively at night and are adept at flying through forests near their nests during the night.

In addition to the limited data available for Hawaiian Petrels and Newell's Shearwaters, there is evidence that many other species of birds detect and avoid wind turbines during low-light conditions (Winkelman 1995, Dirksen et al. 1998, Desholm and Kahlert 2005, Desholm et al. 2006). For example, seaducks in Europe have been found to detect and avoid wind turbines >95% of the time (Desholm 2006). Further, natural anti-collision behavior (especially alteration of flight directions) is seen in night-migrating Common and King eiders (*Somateria mollissima* and *S. fischeri*) approaching human-made structures in the Beaufort Sea off of Alaska (Day et al. 2005) and in diving ducks approaching offshore windfarms in Europe (Dirksen et al. 1998). Collision-avoidance rates around wind turbines are high for Common Eiders in the daytime (Desholm and Kahlert 2005), gulls (*Larus* spp.) in the daytime (>99%; Painter et al. 1999, cited in Chamberlain et al. 2006), Golden Eagles (*Aquila chrysaetos*) in the daytime (>99%; Madders 2004, cited in Chamberlain et al. 2006), American Kestrels (*Falco sparverius*) in the daytime (87%, Whitfield and Band in prep., cited in Chamberlain et al. 2005), and passerines during both the day and night (>99%; Winkelman 1992, cited in Chamberlain et al. 2006). Further, the proportion of nocturnal migrants that detect and avoid turbines must be very high because the average annual fatality rates of nocturnal migrants of a few birds/MW generally are far lower than average annual exposure rates of nocturnally-migrating birds as measured by radar (Cooper, unpubl data).

We agree with others (Chamberlain et al. 2006, Fox et al. 2006) that species-specific, weather-specific, and site-specific avoidance data are needed in models to estimate fatality rates accurately. However, the currently-available avoidance data from Kauai and Lanai for Hawaiian Petrels and Newell's Shearwaters and the petrel and shearwater fatality data at KWP I met towers and wind turbines, while incomplete, are consistent with the hypothesis that a substantial proportion of petrels detect and avoid wind turbines, marked met towers, communication towers, and powerlines under normal ranges of weather conditions and visibility (but note that avoidance rates could be lower under inclement conditions). Until further petrel- and shearwater-specific data on the relationship between exposure and fatality rates are available for met towers and wind turbines, we will provide a standard range of assumptions for avoidance rates in our fatality models (i.e., 50%, 95%, and 99% avoidance), along with a discussion of the body of evidence that is consistent with the hypothesis that the average avoidance-rate value is greater than 50% and around 95%. With a 95%-avoidance assumption, the estimated average annual fatality rate at the proposed Kahuku windfarm would be <0.07 Newell's Shearwater/met tower/yr and <0.03 Newell's Shearwaters/wind turbine/yr.

Additional factors could affect our estimates of fatality rates in either positive or negative directions. One factor that would have created a positive bias was the inclusion of targets that were not petrels or shearwaters. Our visual observations (especially during crepuscular periods, when we could use binoculars) probably helped to minimize the inclusion of non-target species, but it is possible that some of our nocturnal radar targets were other fast-flying species that were active during the sampling period (e.g., Sooty Terns, tropicbirds at times, Greater Frigatebirds at times). A second positive bias is our simplistic assumption in the modeling that movement rates of seabirds did not fall as individual fatalities occurred (i.e., we assumed sampling with replacement after fatalities). Given the extremely low movement rates observed in this study, it is likely that the fatality of just a single bird would substantially reduce the average nightly movement rates.

There also are factors that could create a negative bias in our fatality estimates. One example would be if targets were missed because they flew within radar shadows. Because the sampling station provided excellent coverage of the surrounding area, however, we believe that the number of targets that was missed because they passed through the entire area of coverage of the study area within a radar shadow was zero.

At least three factors could affect our fatality estimates in either direction. The first factor is interannual variation in numbers of seabirds visiting nesting colonies. The average hourly movement rate for the current study (~0.3 targets/h in the fall of 2007 and ~0.2 targets/h in the summer of 2008) suggest that rates are consistently very low at this site and that interannual variation is minimal. Some caution in extrapolation of movement rates across years is warranted, however, because there are examples of other sites with high interannual variation in movement rates. For example, mean movement rates on Kauai in fall 1992 were 25% of those in fall 1993, with the lower counts in 1992 being attributed to the devastating effects of Hurricane Iniki on the island just prior to the fledging of chicks (Day and Cooper 1995). Oceanographic factors (e.g., El Niño–Southern Oscillation events) also vary among years and are known to affect the distribution, abundance, and reproduction of seabirds (e.g., Ainley et al. 1994, Oedekoven et al. 2001). Another factor that could cause interannual variation in counts in either direction is overall population increases or declines. For example, a ~60% decline in radar counts of petrels and shearwaters on Kauai between 1993 and 1999–2001 was attributed primarily to population declines of Newell's Shearwaters (Day et al. 2003b).

HAWAIIAN HOARY BATS

Recent data from Appalachian ridge tops in the eastern and from prairie locations in both the US and Canada have indicated that substantial kills of bats, including Hoary Bats, sometimes occur at wind turbines (Kunz et al. 2007b, Arnett et al. 2008). In contrast, while some bats also have been killed by communication towers (Zinn and Baker 1979, Crawford and Baker 1981, Erickson et al. 2002), powerlines (Dedon et al. 1989, cited in Erickson et al. 2002), and fences (Denys 1972, Wisely 1978), the annual fatality rate at those structures has been small (Erickson et al. 2002). We were unable to find any references on bat kills at met towers in the published or unpublished literature. Because of recent fatalities of migratory Hoary Bats at wind turbines on the US mainland (Kunz et al. 2007a), there was interest in having us collect audiovisual data on Hawaiian Hoary Bats during this study, even though the Hawaiian subspecies is non-migratory. Our data indicate that Hawaiian Hoary Bats are present in the Kahuku study area but appear to occur there in very low numbers: only 1 bat was recorded during the 13 nights of this study (i.e., 1 bat in 97 25-min observation sessions, or 0.0004 bats/h). These bats have been recorded on Oahu (Baldwin 1950, Tomich 1986), where their densities are described as "sparse" (van Riper and van Riper 1982), and it is speculated that they formerly were much more abundant on Oahu than they are now (Kepler and Scott (1990). In fact, there is recent speculation that the species has disappeared from Oahu and Molokai (State of Hawaii 2005), although this study indicates persistence on this island and the work of Day and Cooper (2002) does the same for Molokai. More extensive visual and/or acoustic work could be done in the study area to provide better seasonal information on the distribution and abundance of bats there, but it appears that they are rare in the vicinity of the proposed windfarm.

CONCLUSIONS

This study focused on the movement patterns and flight behavior of Hawaiian Petrels and Newell's Shearwaters near the proposed Kahuku windfarm in fall 2007 and summer 2008. The key results of our study were: (1) seabird movement rates were extremely low (0.2–0.3 targets/h) relative to other locations in the Hawaiian Islands; (2) the timing of movements suggested that all of the radar targets that we observed were those of Newell's Shearwaters; (3) Hawaiian Hoary Bats were recorded in the vicinity of the proposed windfarm, but bat movement rates were extremely low (~0.0004 bats/h); (4) an estimated 1.46 Newell's Shearwaters flew within the space occupied by a met tower in an average year and an estimated 0.39–3.81 flew within the space occupied by a wind turbine an average year; and (5) by using a range of assumptions for avoidance rates in our fatality models (i.e., 50%, 95%, and 99% avoidance), we estimated a collision-caused fatality rate of 0.014–0.692 Newell's Shearwaters/met tower/yr and 0.004–0.273 Newell's Shearwaters/wind turbine/yr. The limited avoidance data available for these and other bird species suggest that the proportion of birds that see and avoid the met towers and wind turbines will be substantial and will be enhanced by marking; however, we emphasize that, until data are available on petrel and shearwater collision-avoidance behavior at met towers with marked guy wires and at wind turbines, the exact proportion will remain unknown. We provide a discussion of the body of evidence that, while incomplete at this time, is consistent with the hypothesis that the average avoidance-rate value is greater than 50%.

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Appendix 4

CONFIDENTIAL DRAFT REPORT

Kahuku Wind Power Wildlife Monitoring Report and Fatality Estimates for Waterbirds and Bats (October 2007 – April 2009)

By
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1.0 INTRODUCTION

Firstwind (formerly UPC Hawaii Wind Partners, LLC) has proposed to develop a 30 mega-watt wind power facility near the town of Kahuku on the island of Oahu, Hawaii. Kahuku Wind Power is situated one mile from the James Campbell Wildlife Refuge which harbors a significant portion of Hawaii's endangered waterbirds (Fig. 1). Avian and bat surveys were conducted to assess the risk of the proposed wind facility to Federal or state-listed threatened or endangered species that may be found on site or may transit through the site. When the project is completed, Kahuku Wind Power will consist of 12 turbines and one permanent meteorological (met) tower.

The goals of the study were to:

1) quantify the level of bird and bat activity on site using visual surveys and Anabat detectors (for bats) with emphasis on characterizing the flight patterns and activity of threatened and endangered species within these groups;
2) conduct waterbird surveys at nearby wetlands to characterize flight activity and diurnal or seasonal variations in abundance or activity (if any) and
3) estimate fatality rates of threatened and endangered species due to operation of turbines and met towers

2.0 METHODS

2.1 Quantifying Bird Activity

Point count stations (Stations B to K, Fig. 1) were selected to provide maximum survey coverage of the project area. Ten point count stations were established on the site and used during the survey period from October 2007 to December 2008 (Fig. 1). Four to eight point count stations were surveyed during each session and sessions were conducted in the morning (0600 – 1000 h), afternoon (1000 – 1400 h) and evening (1400 – 1800 h). Each point count lasted 20 minutes per station. Two observers using 10 x 50 binoculars with a 6.5 degree field of vision were present at each point count and all passerines, owls (Strigiformes) and doves (Columbiformes) within a 200 m radius of the count location were recorded. Bird species aurally detected within 200 m radius were also recorded. Waterbirds and seabirds, which are larger and more visible were recorded to within a 400 m radius of the count station. Data recorded include time of day, bird species, size of flock, flight direction, flight altitude, distance between bird/s and observer, habitat, location (on site or off site) and sex and age of bird where possible. Weather conditions were also documented. Wind speed and wind direction were recorded with a Kestrel 4500 (Nielsen Kellerman, USA), % cloud cover and visibility were estimated visually and precipitation was categorically documented.

Three additional point count stations were established from June - December 2008 along roads running along wetlands at the north-east of the project site (Stations 77, 78 and 79; Fig. 1). These additional point counts were established to describe the flight activity of endangered Hawaiian waterbirds that may not be adequately surveyed at the established on-site point count locations. Survey methods at these point count stations followed the protocol described above. However, due to the greater number of endangered waterbirds in the surveyed wetlands, point counts were confined to a radius of 200 m for all bird species. In addition, bird flight paths that crossed the road moving from the wetlands to the uplands or from vice versa were also recorded. This behavior was quantified and used as a measure the likelihood of waterbirds flying over the upland Kahuku Wind Power site.

Predominant flight directions were determined for all point counts on site and at the surveyed wetlands. The distribution of flight direction was tested using a Chi-Square Goodness-of-Fit to determine if flight paths were random or directional in nature. Flight activity at each point count station on site at Kahuku Wind Power was tested using a one-way ANOVA with replicates to determine if some stations had higher flight activity than other stations. The data was log-transformed to normalize the data before running the analyses. Post-hoc Tukey's pairwise comparisons were conducted to determine which point count stations had higher rates of flight activity. All analyses were conducted using the statistical software SYSTAT (version 12, Systat Software, Inc.).

2.2 Quantifying bat activity

Nocturnal visual surveys and acoustic monitoring using bat detectors were used to quantify bat activity at the Kahuku Wind Power facility. Nocturnal visual surveys were conducted twice a month from October 2007 to December 2008. Four to eight point counts were surveyed for 20 minutes during each field session using the avian point count stations on the project site. Night vision goggles (Kerif ITT PVS-7 F5001 Series) and infra-red spotlights (Brinkmann Q-beam Max Million III) were used to detect bats to a distance of 30 m.

Three to five Anabat detectors (Titley Electronics, NSW, Australia) were deployed at any one time at various locations at the Kahuku Wind Power site from April 2008 to April 2009 (Fig. 2). Anabat detectors record any ultrasonic sounds emitted up to a radius of approximately 30 m from the device. These sounds are subsequently downloaded and analyzed by examining the sonograms of recorded sound files to confirm the presence of bats by identifying their echolocation (ultrasonic) calls. Anabat detectors were moved to new locations if they did not detect any calls for at least a month. Bat activity was quantified by the number of call sequences recorded (regardless of number of bat calls) and the number of bat passes (a sequence with three or more calls) per detector night. A bat call is one frequency modulated sweep, while a call sequence consists of a continuous recording of one or more bat calls. A call sequence with three of more calls qualifies as a bat pass (Kunz et al. 2007).

2.3 Calculating Fatality Estimates for Koloa Maoli-like Ducks

The koloa maoli-like ducks (or Hawaiian duck hybrids) are not endangered, but are hybrids of the endangered koloa maoli (*Anas wyvilliana* or Hawaiian duck) and the mallard (*Anas platyrhynchos*) and are a waterbird species of interest as they are likely to exhibit similar behaviors to the endangered koloa maoli.

Fatality estimates closely follow the model by Day and Cooper (2008) with modifications. The model includes movement rates (average passage rates over the site), horizontal interaction probabilities (probability of a bird encountering a turbine), exposure indices (the number of birds actually encountering a turbine within a given time frame), and fatality probability (the likelihood of fatality upon striking a structure). Different avoidance rates (probability of flying around the airspace of a structure rather than entering it) were also applied. Fatality estimates were divided into three parts; fatality at heights of the rotor swept zone (RSZ, 32 – 128 m), fatality from colliding with the tubular towers below the RSZ (< 32 m), and fatality upon collision with the met tower.

2.3.1. Passage rates

The average passage rate (flocks/hr/ha) of koloa maoli-like ducks was determined from koloa maoli-like duck flight activity rates at all point count stations on site. As koloa maoli-like ducks are large and visible, a 400 m radius was assumed for each point count. A uniform passage rate was assumed over the entire site encompassing the locations of all turbines and met towers. This enabled one hectare (ha) plots to be centered on each turbine and the passage rate of koloa maoli-like ducks in and around the airspace of each turbine to be calculated.

2.3.2 Calculating Horizontal Interaction Probabilities

The horizontal interaction probability for the RSZ was calculated on the assumption that the volume of the RSZ was a solid sphere with a radius of 47 m (the length of the turbine blades) (Fig. 3). The interaction probability for one RSZ (i.e., probability of encountering one RSZ of a turbine) is the proportion of the volume of one RSZ over the volume of a 1 ha plot from a height of 32 m to 128 m centered on each turbine (Fig. 3).

The interaction probability of one tubular tower (i.e., probability of encountering the tubular tower of the turbine below the RSZ) is the proportion of the volume of the tubular tower over the volume of a 1 ha plot from ground level to 32 m centered on each turbine (Fig. 3).

The interaction probability of one met tower is the proportion of the volume of the tower (80 m high) over the volume of a 1 ha plot centered on the tower at a height less than 80 m. The volume of the met tower consists of the volume of the lattice structure modeled as a solid structure (Fig. 4). The model also over-estimates the volume of the met tower by assuming a straight line taper from the base to the top, rather than a curve.

2.3.3 Exposure indices

Exposure indices estimate the likelihood of collision of a bird when it is in the airspace of the structure and the likelihood of fatality upon collision.

2.3.4 Fatality Probability Factors

Fatality probability factors within the RSZ (i.e., probability of striking a blade on frontal approach and probability of fatality if striking blade) are derived from the model developed by Day and Cooper (2008) for the Clipper C-96 turbine. Similarly, the fatality probability factors for the tubular towers of the turbines and met towers (probability of striking a tower if in airspace and probability of fatality if striking the tower) are also derived from same model (Day and Cooper 2008).

2.3.5 Avoidance Rates

Low mortality of waterbirds has been documented at wind turbines situated coastally (as is the proposed Kahuku Wind Power project), despite the presence of high numbers of waterbirds in the vicinity (e.g., Kingsley and Whittam 2007). Studies at wind energy facilities proximally located to wetlands and coastal areas have shown that waterbirds and shorebirds are among the birds most wary of turbines and that these birds readily "learn" to avoid the turbines over time (Koford et al. 2004, Jain 2005, Carothers 2008). Thus avoidance rates of 90%, 95% and 99% were applied to this project to provide a range of reasonable and prudent fatality estimates.

2.4 Calculating Fatality Estimates for Bats

Extensive monitoring of bat activity at pre-existing wind farms has shown a strong positive relationship between the total number of bat passes per night for each detector on site with estimated fatalities per turbine per year (Kunz et al. 2007). Essentially, the number of bat fatalities per turbine per year is almost equivalent to the number of bat calls per night for each detector on site (see Table 1). However, the data on echolocation passes reported in these studies did not distinguish among species. Moreover, echolocation calls were recorded at different altitudes at some sites and only at ground level at others. In addition, echolocation call data were collected after the wind energy facilities were constructed. Thus, it is unclear whether preconstruction bat pass data, as in the case of Kahuku Wind Power, would have shown a different pattern. Furthermore, the relationship between preconstruction call rates and fatality rates may not exist or may not be as strong if modifications to forested habitats (thereby creating linear landscapes) or the turbines themselves attract bats (Kunz et al. 2007).

Thus, bat fatality estimates per turbine at Kahuku Wind Power was calculated using the following assumptions:

1) the change in landscape or construction of turbines does not attract bats to the area,
2) post-construction bat activity remains the same as pre-construction bat activity, and
3) the number of bat fatalities per turbine per year is equivalent to the number of bat passes per night for each detector on site (as shown by Kunz et al. 2007)

If the level of bat activity recorded at the Kahuku Wind Power site is low, the estimated take of bats per turbine will be based on the number of call sequences per detector night, rather than the number of bat passes (Assumption 3). This will provide a more conservative fatality estimate.

Potential for bats to collide with met tower is considered negligible because these objects are stationary and should be readily detected by the bats. Of 64 wind turbines at Mountaineer Wind Energy Center in the Appalachian plateau in West Virginia, bat fatalities were recorded only at operating turbines and not at a non-operational turbine during the study period (Kerns et al. 2005). This supports the expectation that the presence of stationary structures such as met tower and cranes should not result in bat fatalities.

3.0 RESULTS

3.1 Diurnal Point Count Surveys

3.1.1 On-site Surveys

Avian point count surveys were conducted for 64.9 hours between October 2007 and December 2008. Point count surveys were conducted by First Wind from October 2007 to May 2008, and by SWCA from June 2008 to December 2008. Twenty three bird species (and 6 introduced mammal species were observed during the diurnal point count surveys (Table 2). For ESA "related" listed species, only koloa maoli-like ducks (*Anas* sp) apply, and were seen on three occasions at the northern portion of the Kahuku Wind Power site.

Native resident and migratory birds protected under the Migratory Bird Treaty Act (MBTA) include the greater frigate bird (*Fregata minor*), Pacific golden plover (*Pluvialis fulva*) and ruddy turnstone (*Arenaria interpres*). Migratory shorebirds arrived at Kahuku Wind Power in September and departed in May. Data so far indicates that Pacific golden plover are more frequently observed in flight (0.57 flocks/hr/point count) than the ruddy turnstone (0.02 flocks/hr/point count) at Kahuku Wind Power. The great frigate bird is resident year round in Hawaii and flies over the site occasionally (0.17 flocks/hr/point count, Table 2).

Most flight activity at Kahuku Wind Power was dominated by introduced bird species. Common myna (*Acridotheres tristis*), red-vented bulbuls (*Pycnonotus cafer*), cattle egret (*Bubulcus ibis*), Japanese white-eye (*Zosterops japonicus*), finch species, zebra dove (*Geopelia striata*) and spotted dove (*Streptopelia chinensis*) accounted for 85% of the bird activity observed at Kahuku Wind Power. Seventy-five percent of all flights observed (3rd quartile) were less than 15 m altitude (Fig. 5, see box plot). Ninety three percent of all flights observed were below the RSZ; only 3.4% of all flocks flew within the RSZ and 0.05% above the RSZ. The species most frequently observed flying within the RSZ were cattle egrets (Table 3). The only native species flying within the RSZ were the great frigate bird and koloa maoli-like ducks. Figure 5 also illustrates flight directions (of all bird species combined) at the different point count stations within the Kahuku Wind Power site. Predominant flight directions (> 20% of observed flights) were present for seven of ten point count stations (Table 4) and were mostly perpendicular to the proposed turbine rows (Fig. 5). Bird activity (flights/hr) varied with point count location (range 13.71 – 30.60 flight/hr) but statistical analyses indicate that only point count station D had significantly higher bird activity than one other station (Station J).

3.1.2 Adjacent Wetland Bird Surveys

Observations of endangered Hawaiian waterbirds were conducted at wetlands closest to the project site. The wetlands comprised mostly of active and abandoned shrimp ponds and were surveyed by SWCA biologists between June and December 2008. Hawaiian stilt (*Himanotopus mexicanus knudseni*) and Hawaiian coot (*Fulica alai*) were observed in flight at the adjacent wetlands as well as koloa maoli-like ducks. No Hawaiian moorhen (*Gallinula chloropus sandvicensis*) were observed.

Compared to the flight activity of koloa maoli-like ducks observed in the adjacent wetlands (0.33 flocks/hr/ha, see below), the activity of koloa maoli-like ducks over the Kahuku Wind Power site is low (0.05 flocks/hr/ha). The average flock size for koloa maoli-like ducks as observed in adjacent wetlands was 2.0 birds per flock (range 1 – 9). Only 2.7 % of the observed flight altitudes were within the RSZ; the remainder below the RSZ (Fig. 6). Koloa maoli-like ducks freely moved between the wetlands and uplands. Thirty-three % (n = 45) of all observed flocks (n = 147) in flight were from the wetlands to the uplands or from the uplands to the wetlands. Flight direction was predominantly from the north and west (X^2=51.1., df=7, p=0.000). Most ducks were observed flying between recently harvested cornfields (located below Kahuku Wind Power) and the wetlands. This provides confirmation that koloa maoli-like ducks will occasionally transit past the Kahuku Wind Power site. Flight activity in the adjacent wetlands is highest in the mornings and the evenings and low in the afternoon (X^2=69.9, df=2, p=0.000).

No other state endangered or other ESA-listed or candidate species have been observed at Kahuku Wind Power since the initial surveys began in October 2007. Hawaiian stilt were often seen flying within the adjacent wetlands, but only observed once flying from uplands to wetland (1.3%, 1 of 76 flocks, Fig. 7). This supports the lack of observations of Hawaiian stilt flying over Kahuku Wind Power. The average flock size of Hawaiian stilt was 1.5 birds per flock and predominant flight direction was also from the north and west (X^2=81.9, df=7, p=0.000). As most flights were short between nearby ponds, 75 % of the observed flight altitudes were below 5 m. However, for the few longer-distance flights (100 m or more), the maximum flight height was 30 m, just below the turbine's RSZ. Flight activity in the adjacent wetlands was highest in the mornings and lower in the afternoons and evenings (X^2=21.3., df=2, p=0.000).

Of 31 observations of Hawaiian coot, only one individual was seen in flight between ponds in the adjacent wetlands. No Hawaiian coots were observed flying upland from the wetlands or vice versa. These observations together indicate that Hawaiian coot are highly unlikely to be flying over Kahuku Wind Power at any time and support the absence of observations of Hawaiian coot in flight over Kahuku Wind Power during the 15-month long observations on site.

Hawaiian moorhen were not observed at adjacent wetlands either in flight or on the ground, although they were likely present. This is not surprising considering the species secretive and highly sedentary behavior (USFWS 2005). These factors indicate that Hawaiian moorhen are highly unlikely to be flying over Kahuku Wind Power at any time and also support the absence of observations of Hawaiian moorhen in flight over Kahuku Wind Power during the 15-month long observations on site. Due to the lack of wetlands at Kahuku Wind Power, waterbirds are not expected to be present (either resident or vagrant) on the grounds of Kahuku Wind Power (SWCA 2008).

3.2 Nocturnal Surveys

3.2.1 Visual Surveys

Eighteen hr of nocturnal visual surveys were conducted at Kahuku Wind Power between October 2007 and December 2008. Nocturnal surveys were conducted by First Wind from October 2007 to May 2008, and SWCA from June 2008 to December 2008. No bats were observed during the entire observation period. Only one incidental visual sighting of the Hawaiian hoary bat was recorded in July 2008, during a radar survey for seabirds.

3.2.2 Acoustic Monitoring

Eleven sites at Kahuku Wind Power were acoustically sampled from April 2008 to April 2009 (Figure 2). A total of 1285 detector nights were sampled between April 2008 and April 2009 (Table 6). Hawaiian hoary bat call sequences were recorded on 20 occasions from three locations (Anabat A in late November, D, and E) from April 2008 to April 2009 (Table 6). The limited data suggest that bat activity may increase from June to September and are lowest or absent from December to February. The peak activity is within the period bat numbers are expected to increase in the lowlands because of migration from higher altitudes (Menard 2001). The period of low bat activity coincides with bat migration from lowlands to higher altitudes (Menard 2001). However, due to the very small sample sizes, it is not possible to draw any conclusive patterns herein, and bats may be present on-site year round. Anabat detectors on the site estimate an average hoary bat activity rate of 0.01 bat passes/detector/night or 0.016 call sequences/detector per night. The detection rates at Kahuku Wind Power are 40-fold lower than detection rates at Hakalau National Wildlife Refuge (0.66 passes/detector/night, Bornaccorso, USGS unpublished report). Bat activity at Kahuku Wind Power is also less than half that at the Kaheawa Wind Pastures, which has an activity rate of 0.04 bat call sequences/detector/night (First Wind 2008).

3.3 Estimated Fatality Rates of Koloa Maoli-like Ducks

Three flocks of koloa maoli-like ducks were observed during the 15month avian survey resulting in an average passage rate of 0.001flocks/hr/ha over the project site (Table 7). Incidental sightings include observations of a flock of koloa maoli-like ducks in May 2007, June and December 2008. Using flight altitudes observed in the adjacent wetlands, we estimate that 2.7% of all flights occurring over Kahuku Wind Power occur within the RSZ with the remaining below the RSZ (Table 8).

The estimated fatality rate for koloa maoli-like ducks entering the RSZ ranges between 0.0002and 0.002 koloa maoli-like ducks/RSZ/year assuming 99% and 90% collision avoidance rate respectively (Table 9). Fatality rates due to koloa maoli-like ducks striking the tubular towers of the turbines are even lower at 0.0001 and 0.001 koloa maoli-like ducks /tower/year, assuming a 99% and 90% avoidance rate respectively. Combined, the estimated fatality rate for koloa maoli-like ducks at a turbine at Kahuku Wind Power is between 0.0003 and 0.003 birds/turbine/year or 0.004 to 0.038 birds for twelve turbines per year combined.

Fatality rates due to koloa maoli-like ducks striking the met towers of the turbines are 0.00005 to 0.0005 birds /tower/year, assuming a 99% and 90% avoidance rate respectively).(Table 10).

The total fatality at all turbines and met towers on the site is estimated between 0.004 0.038 koloa maoli-like ducks/year (9% and 90% avoidance rate respectively) (Table 11). This result is not unexpected due to the low passage rates observed on site. Studies of wind energy facilities located in proximity to wetlands and coastal areas have shown that waterbirds and shorebirds are among the birds most wary of turbines and that these birds readily learn to avoid the turbines over time (Carothers 2008). Avoidance behavior has also been documented by nēnē at the existing operating facility on Maui (Kaheawa Wind Power 2008). Thus, the estimated take at 95% avoidance (95% of the birds that approach the turbine successfully avoid it) is used as the basis of the take estimates. The fatality rate at 95% avoidance for koloa maoli-like ducks was estimated at 0.02 birds/year for all 12 turbines and one permanent met tower on site.

3.4 Estimated fatality rates of Hawaiian hoary bat

Based on substantial sampling effort (1285 detector nights between April 2008 and April 2009) the estimated take/turbine/year at Kahuku Wind Power with a bat activity of 0.016 bat call sequences/detector/night is 0.016 bats/turbine/year. This results in a total take of 0.19 bats/year for all twelve turbines on the site.

4.0 CONCLUSION

Kahuku Wind Power avifauna is comprised primarily of introduced birds. Native birds were occasionally observed transiting the site; however no resident native avifauna was recorded. Of the waterbirds, only the koloa maoli-like ducks were observed transiting the site and are at risk of colliding with the turbines. However the estimated fatality rate was small, approximating two ducks every 100 years. No endangered waterbirds were observed flying over the site and the lack of observations is supported by the flight patterns of these species in the adjacent wetlands.

Hawaiian Hoary bats are present at Kahuku Wind Power, but activity rates were very low compared to other sites. The estimated fatality of Hawaiian hoary bats is approximately 2 bats every ten years.

Table 1 Fatality and bat activity indices at 5 wind-energy facilities on the mainland United States (from Kunz et al. 2007).

Study area	Inclusive dates of study*	Bat mortality (no/turbine/ yr)	Bat activity (no./detector/ night)	Total detector nights	Source
Mountaineer, WV	31 Aug-11 Sep 2004	38	38.2	33	E.B. Arnett, Bat Conservation International, unpubl. Data
Buffalo Mountain, TN	1 Sep 2000-30 Sep 2003	20.8	23.7	149	Fieldler 2004
Top of Iowa, IA	15 Mar-15 Dec 2003, 2004	10.2	34.9	42	Jain 2005
Buffalo Ridge, MN	15 Mar-15 Nov 2001, 2002	2.2	2.1	216	Johnson et al. 2004
Foote Creek Rim, WY	1 Nov 1998-31 Dec 2000	1.3	2.2	39	Gruver 2002

* Sample periods and duration of sampling varied among studies, with no fatality assessments conducted or bat activity monitored in winter months.

Table 2. Bird and mammal species observed at Kahuku Wind Power site from October 2007 to December 2008 by First Wind and SWCA.

Common Name	Scientific Name	Bird Activity (flocks/hr/point count)	% of Observed Flight Activity	Rank
Birds				
Common myna	*Acridotheres tristis*	6.37	20.59	1
Red-vented Bulbul	*Pycnonotus cafer*	5.50	17.80	2
Cattle Egret	*Bubulcus ibis*	5.36	17.35	3
Finches and/or white-eyes	-	3.85	12.46	4
Spotted dove	*Streptopelia chinensis*	2.74	8.87	5
Zebra Dove	*Geopelia striata*	2.56	8.28	6
Red-crested Cardinal	*Paroaria coronata*	0.92	2.99	7
Japanese white-eye	*Zosterops japonicus*	0.89	2.89	8
House finch	*Carpodacus mexicanus*	0.62	1.99	9
Pacific golden plover	*Pluvialis fulva*	0.57	1.84	10
Northern Cardinal	*Cardinalis cardinalis*	0.40	1.30	11
House sparrow	*Passer domesticus*	0.35	1.15	12
Great frigate bird	*Fregata minor*	0.17	0.55	13
White-rumped shama	*Copsychus malabaricus*	0.12	0.40	14
Red-whiskered bulbul	*Pycnonotus jocosus*	0.11	0.35	15
Common Waxbill	*Estrilda astrild*	0.09	0.30	16
Nutmeg mannakin	*Lonchura punctulata*	0.06	0.20	17
Koloa maoli-like ducks	*Anas* sp.	0.05	0.15	18
Java sparrow	*Padda oryzivora*	0.05	0.15	18
Chestnut munia	*Lonchura malacca*	0.03	0.10	20
Ring-necked pheasant	*Phasianus colchicus*	0.03	0.10	20
African silverbill	*Lonchura cantans*	0.02	0.05	22
Ruddy turnstone	*Arenaria interpres*	0.02	0.05	22
Unidentified owl	-	0.02	0.05	22
Mammals				
Domestic cattle	*Bos taurus*			
Horse	*Equus caballus*			
Dog	*Canis lupus familiaris*			
Cat	*Felis catus*			
Small Indian mongoose	*Herpestes javanicus*			
Feral pig	*Sus scrofa*			

Table 3. Species composition of birds flying within the RSZ

Bird species	% of species composition within RSZ	Rank
Cattle egret	63.8	1
Common myna	11	2
Great frigate bird	8.7	3
House finch	4.7	4
Red-vented bulbul	4.7	4
Koloa maoli-like ducks	0.8	6
House sparrow	0.8	6
Pacific golden plover	0.8	6
Red-crested cardinal	0.8	6
Spotted dove	0.8	6
Zebra dove	0.8	6

Table 4. Flight activity and predominant flight directions at Kahuku Wind Power point count stations

Stations	Average flight activity (flights/hr)	Predominant flight direction (>20%)	Chi-Square test
B	20.85 (n= 197)	NE	X^2=30.4., df=7, p=0.000
C	29.14 (n= 285)	E	X^2=58.1, df=7, p=0.000
D	44.57 (n= 432)	E	X^2=89.3, df=7, p=0.000
E	17.77 (n= 78)	NE, W	X^2=16.6, df=7, p=0.020
F	22.20 (n= 200)	N, E	X^2=66.2, df=7, p=0.000
G	26.85 (n= 234)	-	X^2=6.0, df=7, p=0.540
H	20.10 (n= 206)	-	X^2=9.3, df=7, p=0.232
I	16.71 (n = 85)	W	X^2=26.3, df=7, p=0.000
J	13.71 (n= 64)	E	X^2= 9, df=7, p=0.253
K	30.60 (n= 131)	E	X^2=18.7, df=7, p=0.009

statistically significant

Table 5. Analysis of flight activity at point count stations by time of day.

Analysis of Variance					
Source	Type III SS	df	Mean Squares	F-ratio	p-value
Point count stations	2.915	9	0.324	2.642	0.007
Error	22.188	181	0.123		

statistically significant

Table 6. Bat activity at Kahuku Wind Power

Year	Month	Nights per Anabat Detector					Total nights	No. of calls sequences	No. of bat passes (> 2 bat calls)
		A	B	C	D	E			
2008	April	21	21	21	21	21	105	1	1
2008	May	27	1	27	27	27	109	1	0
2008	June	30	0	30	20	30	110	4	1
2008	July	31	0	31	31	31	124	3	3
2008	Aug	31	26	31	31	31	150	3	2
2008	Sept	30	30	30	30	30	150	5	3
2008	Oct	31	6	9	19	31	96	1	1
2008	Nov	30	17	30	11	13	101	1	1
2008	Dec	26	23	31	17		97	0	0
2009	Jan			31			31	0	0
2009	Feb		2	28	2	2	34	0	0
2009	Mar		30	27	31	31	119	1	1
2009	April		2	-	27	30	59	0	0
						Total	**1285**	**20**	**13**

Table 7. Koloa maoli-like duck passage rates over Kahuku Wind Power

		400m radius point counts
A	**Total point counts**	167
B	**No. of birds observed**	8
C	**Birds per point count B/A**	0.048
D	**Birds per hour C*3**	0.144
E	**Area sampled (ha) 0.4*0.4*3.14**	50.265
F	**Passage rate (birds/hr/ha) D/E**	0.003
G	**Total project area (ha)**	233.8
H	**Passage rate (birds/hr/site) F*G**	0.668
I	**Passage per day over site**	8.021

Table 8. Fatality estimate of koloa maoli-like ducks within rotor swept zone

	Variable	
	Movement rate	
A	mean movement rate (birds/hr/ha)	0.002859071
B	daily movement rate (birds/day/ha) A*12	0.03430885
C	fatality domain (days)	365
D	annual movement rate (birds/year) B*C	12.52273025
E	proportion birds flying within rotor swept zone (>30m and < 128m)	0.027210884
F	annual movement rate within rotor swept zone (>30m and <128 m) D*E	0.340754565
	Horizontal interaction probability	
G	Volume occupied by rotor swept zone (m3)	463011.84
H	Vol of 1 ha area from minimum to maximum rotor height (>32 to <128m) (m3)	960000
I	Horizontal interaction probability G/H	0.482304
	Exposure index	
J	daily exposure index (birds/rotor swept zone/day) B*E*I	0.000450267
K	annual exposure index (birds/rotor swept zone/yr) F*I	0.16434729
	Fatality probability	
L	Probability of striking a blade on frontal approach	0.156
M	Probability of fatality if striking blade	0.95
N	Probability of fatality if an interaction on frontal approach L*M	0.1482
	Fatality index	
O	Annual fatality rate with 90% exhibiting collision avoidance (birds/turbine/yr) K*N*0.1	**0.002435627**
P	Annual fatality rate with 95% exhibiting collision avoidance (birds/turbine/yr) K*N*0.05	**0.001217813**
Q	Annual fatality rate with 99% exhibiting collision avoidance (birds/turbine/yr) K*N*0.01	**0.000243563**

Table 9. Fatality estimate of koloa maoli-like ducks striking tubular towers

	Variable	
	Movement rate	
A	mean movement rate (birds/hr/ha)	0.002859071
B	daily movement rate (birds/day/ha) A*12	0.03430885
C	fatality domain (days)	365
D	annual movement rate (birds/year/ha) B*C	12.52273025
E	proportion birds below rotor swept zone (>32m)	0.972789116
F	annual movement rate below rotor swept zone (>30m) D*E	12.18197569
	Horizontal interaction probability	
G	Volume occupied by tubular tower (m^3)	486.3232
H	Vol of 1 ha area below blade height (<32m) (m^3)	320000
I	Horizontal interaction probability G/H	0.00151976
	Exposure index	
J	daily exposure index (birds/tubular tower/day) B*E*I	5.07224E-05
K	annual exposure index (birds/tubular tower/yr) F*I	0.018513679
	Fatality probability	
L	Probability of striking a tubular tower if in airspace	1
M	Probability of fatality if striking tubular tower	0.95
N	Probability of fatality upon interaction L*M	0.95
	Fatality index	
O	Annual fatality rate with 90% exhibiting collision avoidance (birds/tower/yr) K*N*0.1	**0.0017588**
P	Annual fatality rate with 95% exhibiting collision avoidance (birds/tower/yr) K*N*0.05	**0.0008794**
Q	Annual fatality rate with 99% exhibiting collision avoidance (birds/tower/yr) K*N*0.01	**0.0001758800**

Table 10. Fatality estimate of koloa maoli-like ducks at met tower

	Variable	
	Movement rate	
A	mean movement rate (birds/hr/ha)	0.002859071
B	daily movement rate (birds/day/ha) A*12	0.03430885
C	fatality domain (days)	365
D	annual movement rate (birds/year) B*C	12.52273025
E	proportion birds below meteorological tower (<60m)	1
F	annual movement rate below meteorological tower (<60m) D*E	12.52273025
	Horizontal interaction probability	
G	Volume occupied by meteorological tower (m3)	420.1840223
H	Vol of 1 ha area meteorological tower (<80m) (m3)	800000
I	Horizontal interaction probability G/H	5.25E-04
	Exposure index	
J	daily exposure index (birds/tower/day) B*E*I	1.80E-05
K	annual exposure index (birds/tower/yr) F*I	6.58E-03
	Fatality probability	
L	Probability of striking a met tower if in airspace	1
M	Probability of fatality if striking tubular tower	1
N	Probability of fatality upon interaction L*M	1
	Fatality index	
O	Annual fatality rate with 90% exhibiting collision avoidance (birds/tubular tower/yr) M*P*0.05	0.000657731
P	Annual fatality rate with 95% exhibiting collision avoidance (birds/tubular tower/yr) M*P*0.05	0.000328866
Q	Annual fatality rate with 99% exhibiting collision avoidance (birds/tubular tower/yr) M*P*0.01	0.0000657731

Table 11. Predicted annual fatality rate of koloa maoli-like ducks at Kahuku Wind Power.

	Turbines (x12)	Met tower	Total fatality
Annual fatality rate with 90% exhibiting collision avoidance (birds/yr)	0.050	0.00066	**0.051**
Annual fatality rate with 95% exhibiting collision avoidance (birds/yr)	0.025	0.00033	**0.025**
Annual fatality rate with 99% exhibiting collision avoidance (birds/yr)	0.005	0.00007	**0.005**

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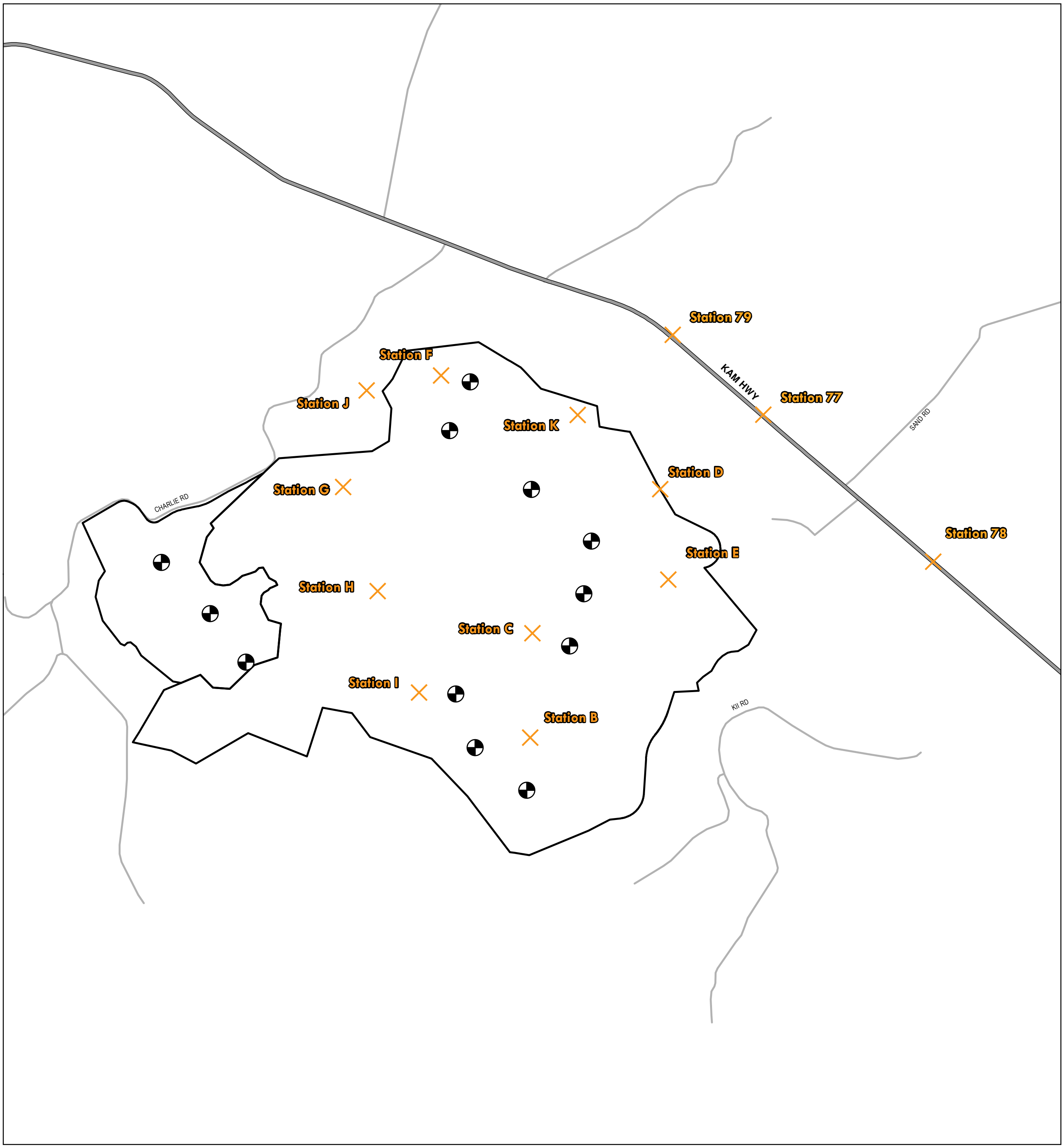


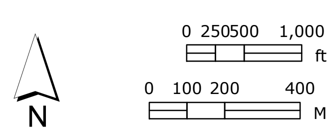
Legend

Turbine/Tower Locations

Point Count Locations

Project Parcel

Figure 1
Station Locations



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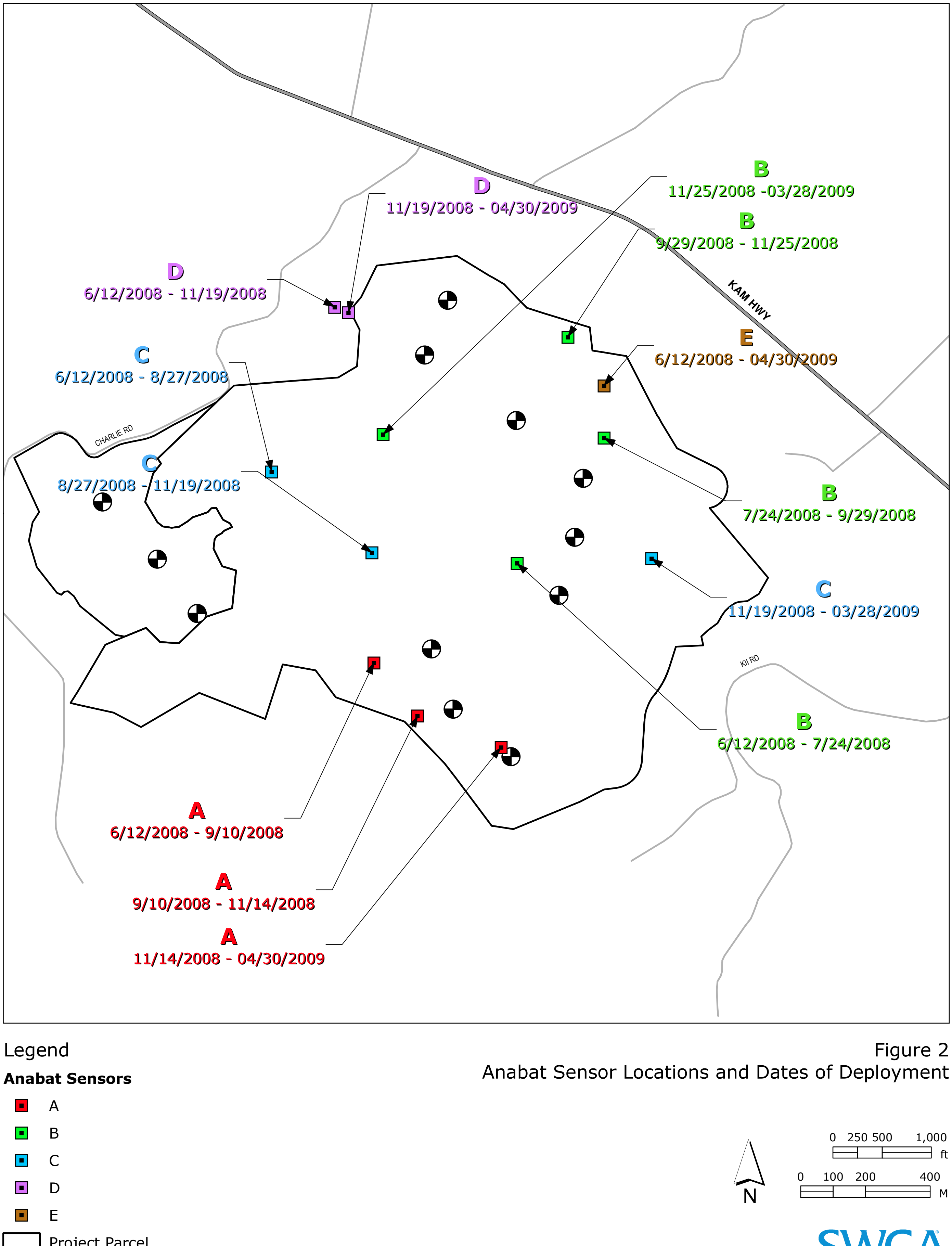

Figure 2
Anabat Sensor Locations and Dates of Deployment

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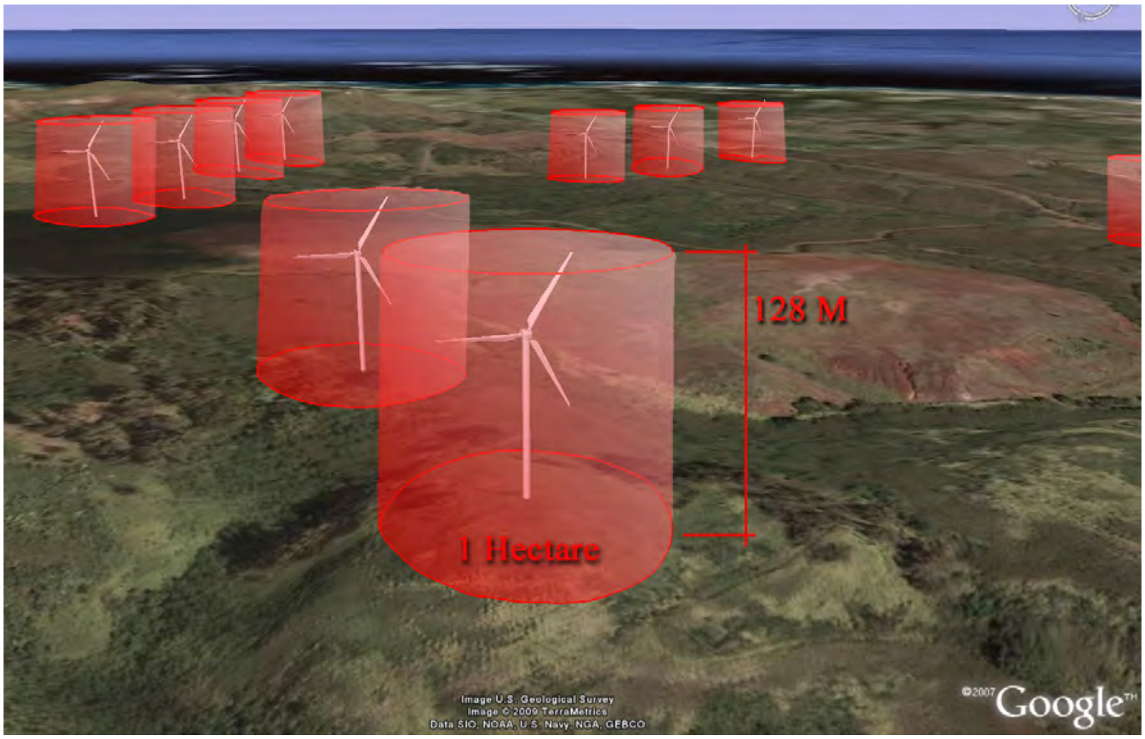

Figure 3. Volume of Turbine to Volume of 1 ha Area.

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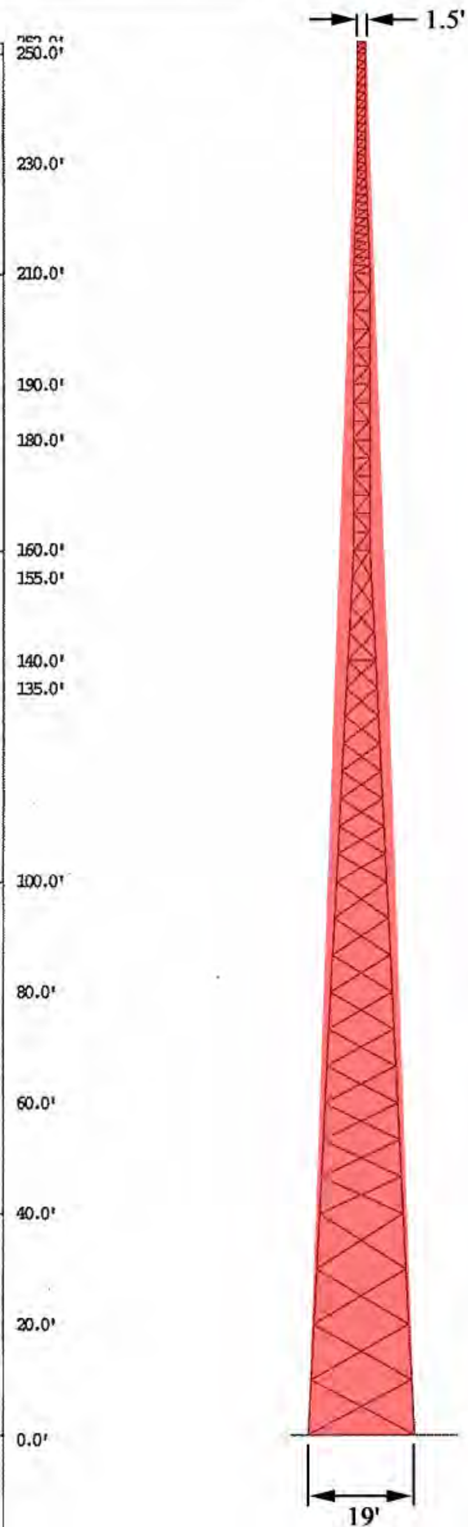
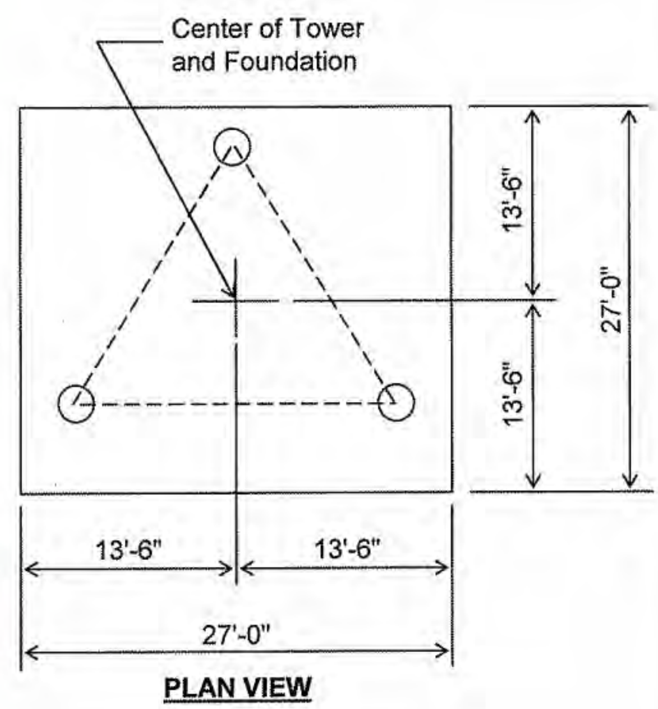
Elevation	Leg	Diagonal	Horizontal	Brace Bolts	Face Width	Panel Height # Panels
250.0'–252.0'	SR 1-1/4"Φ	SR 1/2"Φ	SR 1/2"Φ		1.5'	2
230.0'–250.0'	SR 1-1/4"Φ	SR 1/2"Φ	SR 1/2"Φ		1.5'	28 @ 1.4'
210.0'–230.0'	C	SR 3/4"Φ	SR 3/4"Φ		1.5'	28 @ 1.4'
180.0'–210.0'	B SR 2"Φ	SR 1"Φ	SR 7/8"Φ		3.0'	15 @ 3.3'
160.0'–180.0'	A	I	SR 1"Φ		3.0'	15 @ 3.3'
155.0'–160.0'	4.5000"x0.3370" PIPE	H	J	(1) 5/8"	3.0'	12 @ 5.0'
140.0'–155.0'	4.5000"x0.3370" PIPE	H		(1) 5/8"	3.0'	12 @ 5.0'
135.0'–140.0'	4.5000"x0.3370" PIPE	L 2"x2"x1/8"	J	(1) 5/8"		12 @ 5.0'
100.0'–135.0'	4.5000"x0.3370" PIPE	L 2"x2"x1/8"		(1) 5/8"		12 @ 5.0'
80.0'–100.0'	4.5000"x0.3370" PIPE	G		(1) 5/8"		9 @ 6.7'
60.0'–80.0'	4.5000"x0.3370" PIPE	F		(1) 5/8"		9 @ 6.7'
40.0'–60.0'	4.5000"x0.3370" PIPE	F		(1) 3/4"		9 @ 6.7'
20.0'–40.0'	5.5625"x0.3750" PIPE	E		(1) 3/4"		4 @ 10.0'
0.0'–20.0'	5.5625"x0.3750" PIPE	D		(1) 3/4"	19.0'	4 @ 10.0'
Grade	50 ksi	36 ksi	36 ksi	A325X		



Modeled Volume



PLAN VIEW

Sabre Towers & Poles

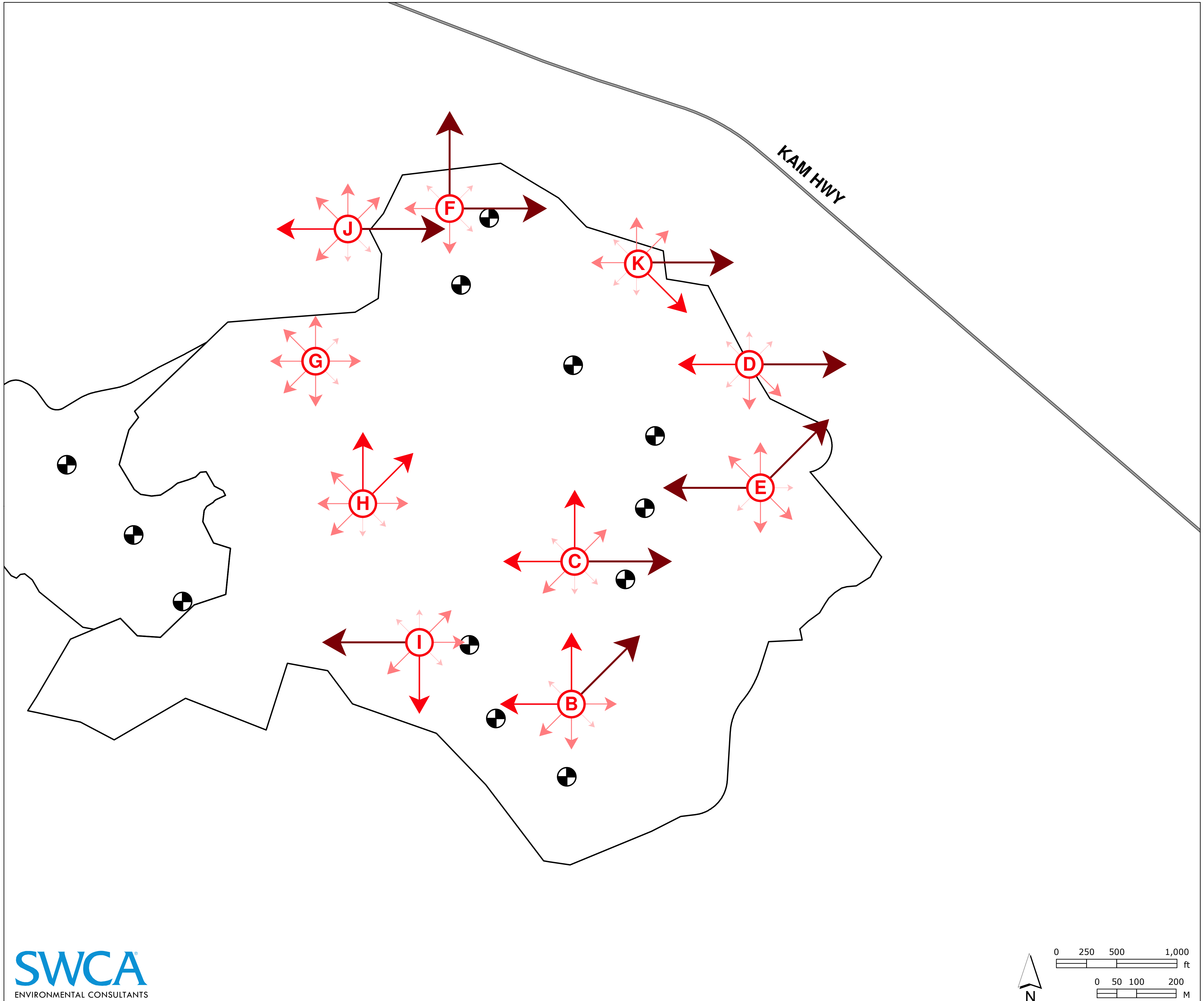
Sabre Towers And Poles

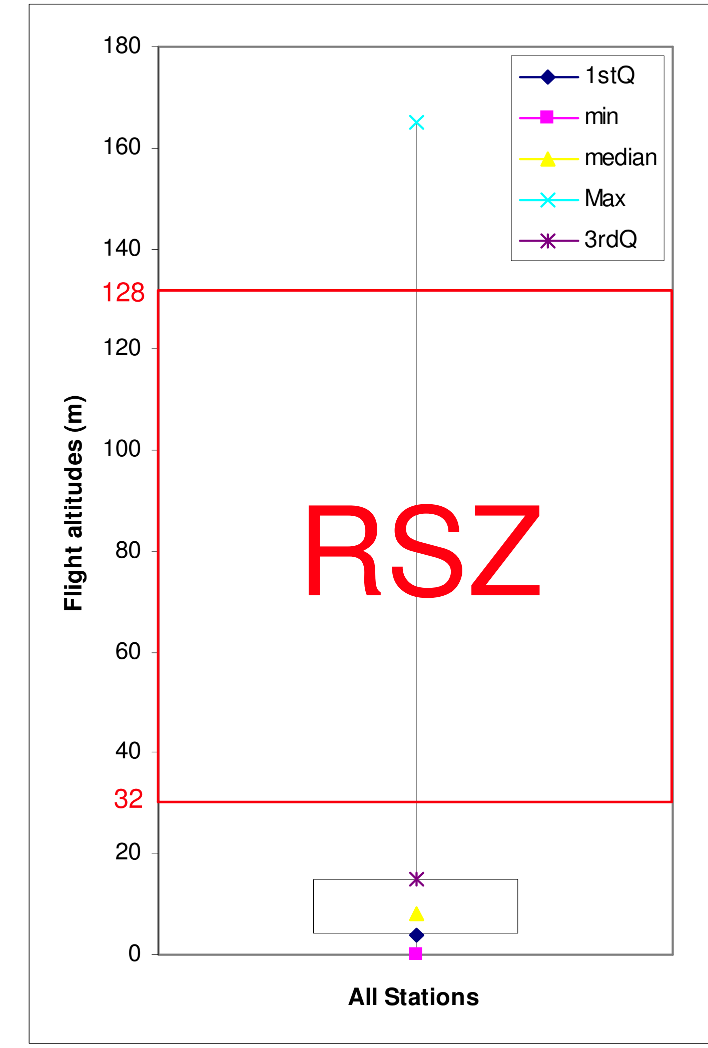
2101 Murray Street (P.O. Box 658), Sioux City, IA 51111

Phone: (712) 258-6690 Fax: (712) 258-8250

Client:	Job No: 09-8316	Date: 19 mar 2009
Location:	Total Height: 252.00'	Tower Height: 252.00'
Standard: TIA 222-G-2005	Design Wind & Ice: 90mph 0" ice & 60mph 0.5" ice	

Project: C:\GUYMAST DESK\-09-8316M.LOD





Legend

Turbine/Tower Locations

Bird Point Count Data Oct 07 - Dec 08

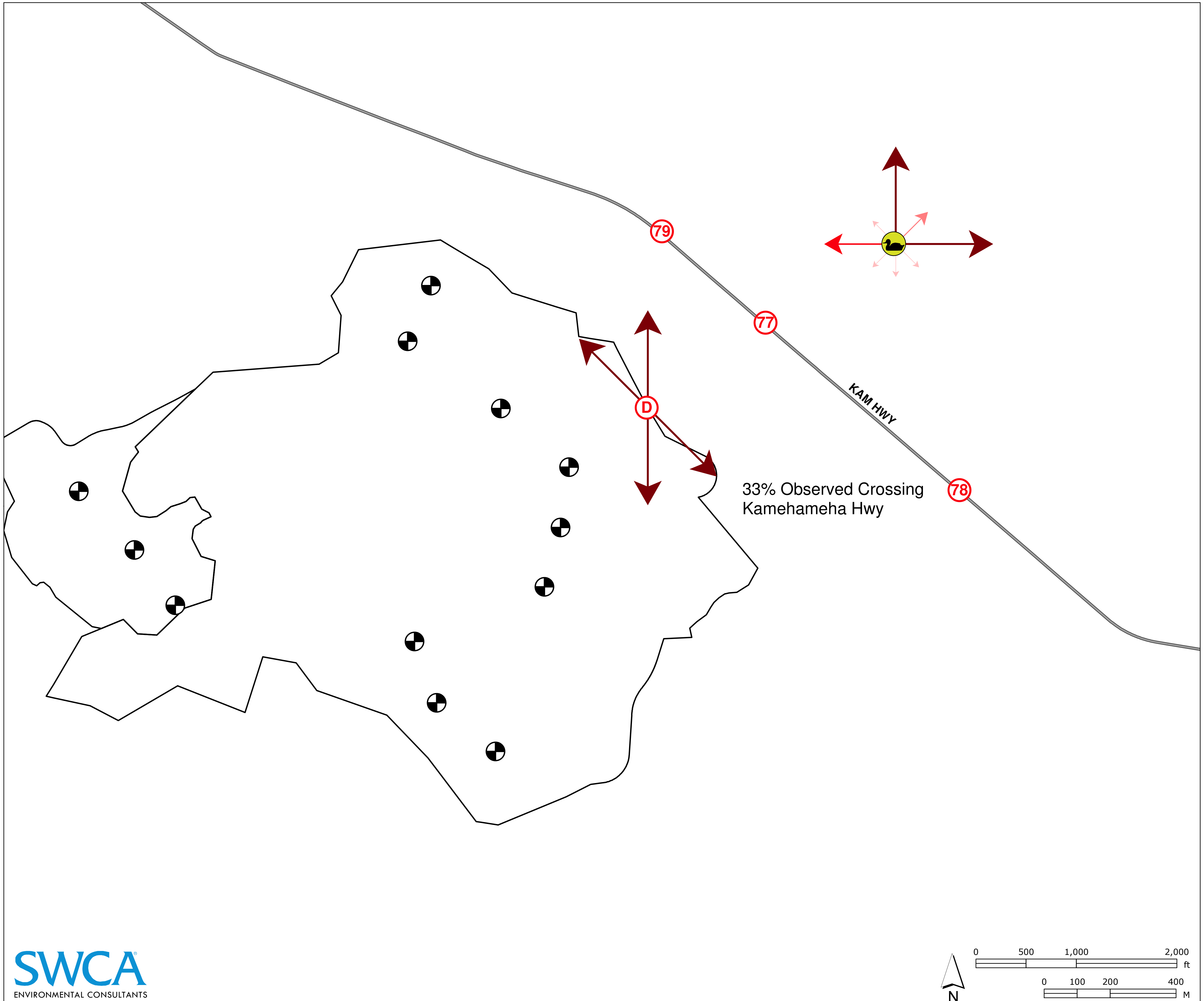
1% - 10%

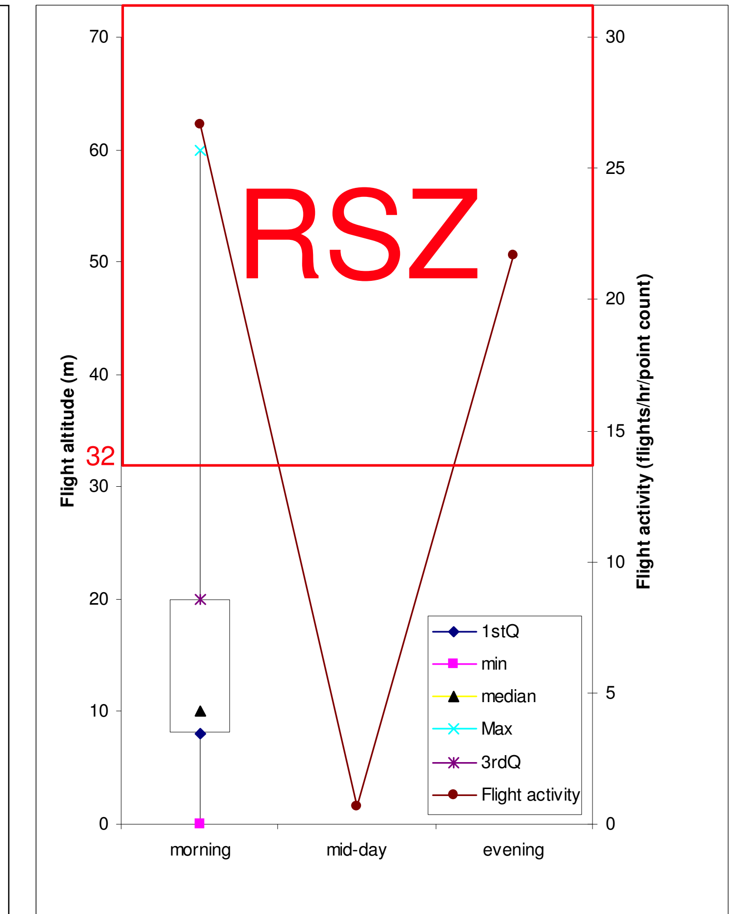
10.1% - 15%

15.1% - 20%

20.1% - 30%

Figure 5
STATION DATA





Legend

Turbine/Tower Locations

Koloa-Maoli Like Duck
Percentage by Direction of Travel

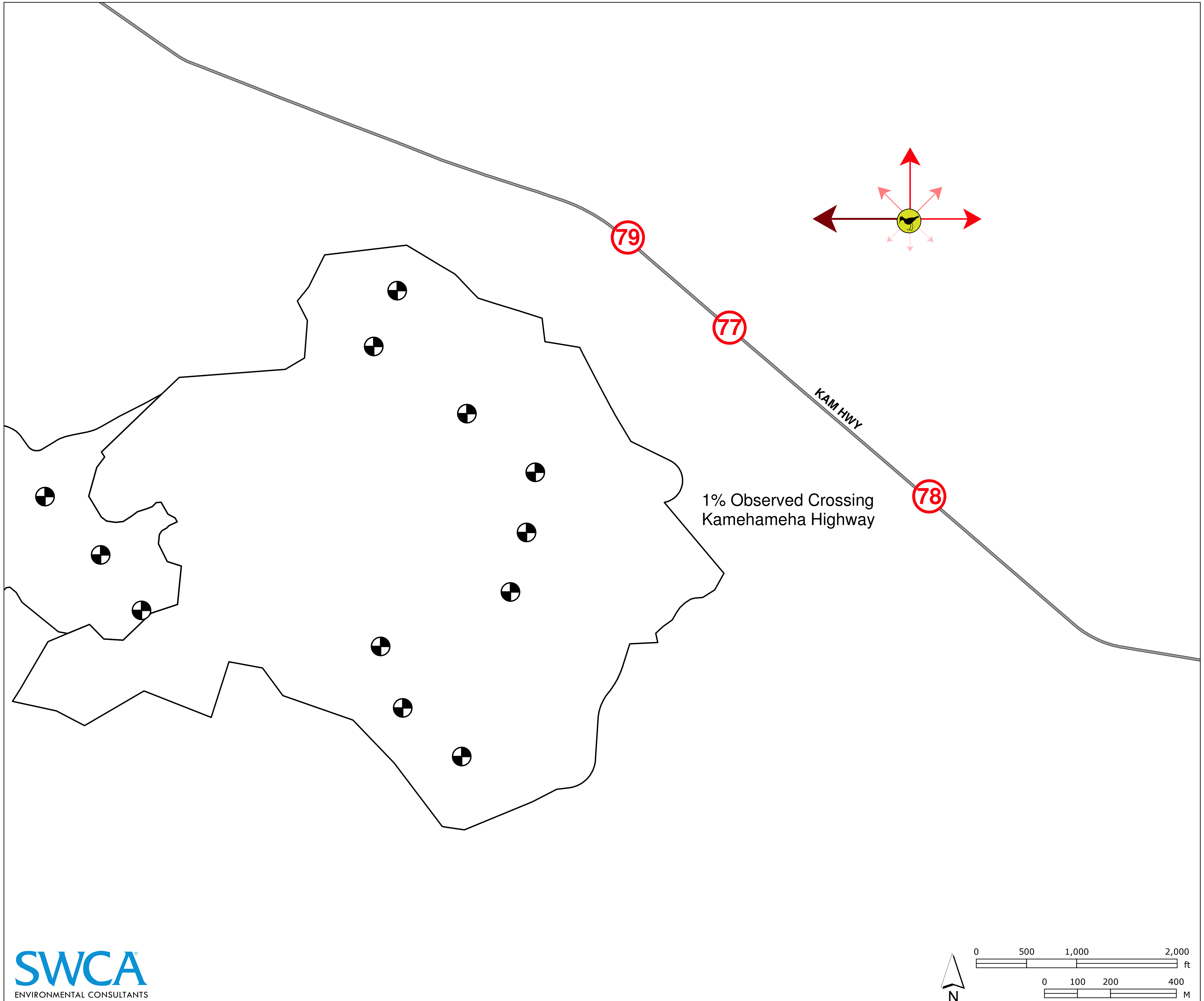
1% - 9.9%

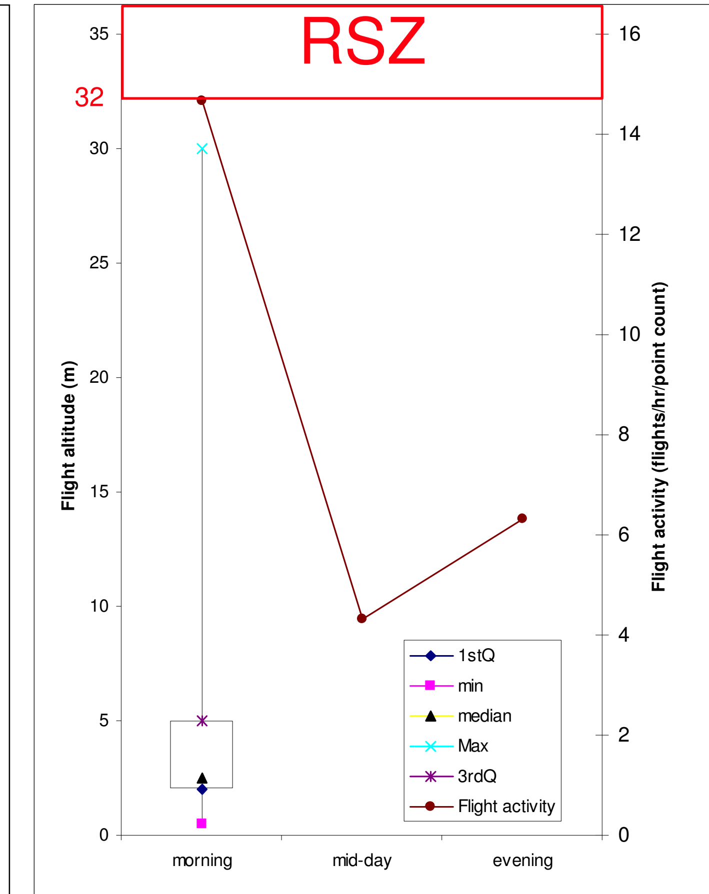
10% - 14.9%

15% - 19.9%

20% - 25%

Figure 5
KOLOA-MAOLI LIKE DUCK OCCURENCES





Legend

Turbine/Tower Locations

Stilt Occurences
Percentage by Direction of Travel

1% - 9.9%

10% - 14.9%

15% - 19.9%

20% - 25%

Figure 6
STILT OCCURENCES

Appendix 5

Life History Information on

Newell's Shearwater (*Puffinus auricularis newelli*),
Hawaiian Petrel (*Pterodroma sandwichensis*),
Hawaiian Duck (*Anas wyvilliana*)and Hybrid,
Hawaiian Stilt (*Himantopus mexicanus knudseni*),
Hawaiian Coot (*Fulica alai*),
Hawaiian Moorhen (*Gallinula chloropus sandvicensis*),
Hawaiian Short-eared Owl (*Asio flammeus sandwichensis*),
and
Hawaiian Hoary Bat (*Lasiurus cinereus semotus*)

Compiled by:
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201 Merchant Street, Suite 2310
Honolulu, HI 96813

1.0 INTRODUCTION

Demographic factors were used to assess indirect take and loss of productivity in section 6.0 (Potential Impacts) and 7.0 (Mitigation) of the HCP. Indirect take and loss of productivity are defined as follows:

> Indirect Take - These are individuals that suffer mortality as the result of a direct take of another individual. For example, the loss of a parent may also result in the loss of eggs or young.
>
> Loss of Productivity - Productivity can be assessed in terms of chicks or fledglings produced per breeding adult per year or the number of fledglings that survive to adulthood per breeding adult per year. When a direct take occurs, loss of productivity can occur between the time the direct take occurs and the time that mitigation is provided. Productivity may also be lost if a juvenile is used as a replacement for the take of a breeding age adult. Factors that need to be taken into consideration when accounting for loss of productivity include demographic factors such as the age and sex of the individuals taken, the time of year the take occurs, and the type of mitigation provided.

Demographic factors for each species covered by the HCP were determined using existing literature. Preference was given to life history information available from Hawai'i, followed by information available for the same species on the North American continent or other areas of the world. If specific information was lacking for any species, life history information for a closely related species was used as a surrogate.

The life history information for the Newell's shearwater (*Puffinus auricularis newelli*), Hawaiian petrel (*Pterodroma sandwichensis*), Hawaiian duck (*Anas wyvilliana*)and hybrid, Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), Hawaiian moorhen (*Gallinula chloropus sandvicensis*), Hawaiian short-eared owl (*Asio flammeus sandwichensis*) and Hawaiian hoary bat (*Lasiurus cinereus semotus*) follow in the sections below.

1.1 Seabirds

1.1.1 Newell's Shearwater

The following demographic factors and assumptions (from Ainley et al. 1997 and as otherwise noted) were used to assess indirect take and loss of productivity of the Newell's shearwater.

Breeding season: The breeding season lasts from June to October each year.

Age at First Breeding: Assumed age 6.

Adults Breeding/Year: On the basis of estimates made by Telfer (1986), incidence of non-breeding is high for Newell's Shearwater on Kaua'i. Only 46% of pairs that actively use a burrow actually breed in a given year (range 30–62 %, *n* = 5 yr, 36– 47 burrows monitored/yr).

Reproductive Success: 66.0% ± 6.4 SD (range 49–75) of nests in which eggs are laid fledge young. Manx Shearwater populations have similar fledging rates (Brooke 1990). For the purposes of the HCP, a 70% average fledging rate is assumed.

Survival to breeding age: Annual adult survivorship of Newell's Shearwater was estimated to be 0.904 ± 0.017 SE, on the basis of allometric equation relating survivorship to body mass in procellariiforms. This figure approximates that estimated for Manx Shearwater by more conventional means (Brooke 1990). Ainley et al. (2001) estimated the survival of fledglings to breeding age to be 24% with the current human induced mortality (powerline mortality, predation and fallout). The expected survival without human induced factors was 33%. For the purposes of the HCP, a survival rate of 24% is assumed.

Number of Broods: One per year.

Clutch Size: One.

Relative Productivity of Males vs. Females: Relative productivity of males and females is assumed to be similar, as with the Hawaiian petrel described below. For the purposes of estimating lost productivity and indirect take, it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

1.1.2 Hawaiian Petrel

The following demographic factors and assumptions (from Simons and Hodges 1998 and as otherwise noted) were used to assess indirect take and loss of productivity of the Hawaiian petrel:

Breeding season: The breeding season lasts from May to October each year

Age at First Breeding: Unknown, but population data suggests breeding starts at age 5-6. Age 5 is assumed for purposes of estimating indirect take and lost productivity.

Adults Breeding/Year: Estimated at 89%.

Reproductive Success: Estimates of annual reproductive success (chicks fledged/eggs laid) at Haleakala, Maui from 1979–1981 (Simons 1985) and 1993 (Hodges 1994) averaged 63.4 % ± 16.0 SD (range 38–82, n = 128). For the purpose of the HCP, the average annual reproductive success of 70% is assumed.

Survival to breeding age: In an analysis of life history by Simons (1984), survival to breeding age was estimated to be 27%. For the purpose of the HCP, it is assumed that 30% of fledged young survive to breeding age.

Number of Broods: One per year.

Clutch Size: One.

Relative Productivity of Males vs. Females: Breeding Hawaiian petrels are apparently monogamous and show a high degree of mate fidelity over subsequent years. Pairs may exhibit courtship behavior that may last one or more seasons prior to breeding. Thus the loss of a male could cause a breeding hiatus for a female even if in pre-breeding condition. Both males and females incubate eggs and provide food for nestlings. For the purposes of estimating lost productivity and indirect take, it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

Sex Ratio: Similar adult male and female survival rates in related species (Warham 1996) suggests a balanced sex ratio, but no published data is available.

1.2 Hawaiian Waterbirds

1.2.1 Pure Hawaiian Duck and Hybrid
From the late 1968 to 1982, Hawaiian duck were reintroduced to O'ahu through captive propagation and release programs (Engilis et al. 2002). As mallards (*Anas platyrhynchos*) were not eradicated from O'ahu prior to introduction, extensive hybridization between Hawaiian duck and mallard has since been documented on O'ahu (Browne et al. 1993, Engilis pers. comm.). Studies on the life history of Hawaiian duck on O'ahu post 1968, may have in fact been studies of Hawaiian duck -mallard hybrids, but the extent of hybridization at that

time is not known. With this in mind, productivity of pure Hawaiian ducks and Hawaiian duck hybrids are assumed to be the same and are treated together in this section. Thus, adjustments to the take of Hawaiian duck to account for lost productivity were developed based on Hawaiian duck demographic factors and assumptions by Chang (1990) and Engilis et al. (2002), unless otherwise noted. Reproductive observations by Chang (1990) were based solely in James Campbell National Wildlife Refuge, Oʻahu and the life history summary by Engilis et al. (2002) includes data only from Kauaʻi and the island of Hawaiʻi. Where life history information was not available, data for the closely related mallard is used from Drilling et al. (2002):

Breeding Season: Nesting occurs year round and the peak breeding season lasts from March to June each year. Breeding lasts approximately three months, witha one month incubation period followed by parental care for two months.

Age at First Breeding: The female Hawaiian duck can breed at age one. Some males may not breed until second year. Breeding age is assumed to be year one.

Adults Breeding per Year: Unknown. Assumed to be 100% though Hawaiian duck may not rear any broods in a given geographic area, particularly during drought years (Engilis and Pratt 1993).

Number of Broods: Likely only one per year for wild populations.

Clutch Size: Clutch sizes of the Hawaiian duck at James Campbell Wildlife Refuge on Oʻahu average 7.3 eggs ± 0.16 SE (n = 174).

Reproductive Success: Chicks hatched/nest for Hawaiian duck on James Campbell Wildlife Refuge on Oʻahu is 3.5 chicks ± 0.24 SE (n = 174, 48% hatching success). Hawaiian duck fledging success (fledglings/chick) is not available but fledgling success for the mallard is 35% in N. Dakota resulting in 1.225 (= 0.35*3.5) fledglings per pair.

Survival to Breeding Age: No survival data currently exists for the Hawaiian duck. It has been demonstrated that for mallards, survival rates generally do not differ significantly among geographic areas or years. The survival rates of mallard juvenile males is estimated to be 48–63% and for juvenile females 46–61% (Drilling et al. 2002). For the purposes of estimating lost productivity and to provide additional benefit to the species, it is assumed that survival to breeding age for the Hawaiian duck is 65%.

Relative Productivity of Males vs. Females

Nest construction and incubation are by the female Hawaiian duck only. To date, no other parental care information is available for the Hawaiian duck. However, the observed behavior by Hawaiian duck pairs is very similar to the parental care expressed by mallards. Using mallards as a surrogate species, parental care by mallards is as follows. Only mallard hens care and defend the young until they can fly. With regards to parental feeding, the hen leads the young to water and abundant food and the ducklings feed themselves. For the purposes of estimating indirect take, it is assumed that males contribute nothing to indirect take and females 100%.

Sex ratio: The sex ratio of mallards under natural conditions is male biased and the ratio approximates 1.1:1 (males:females, Ohde et al. 1984, Johnson and Sargeant 1977). The same ratio of 1.1:1 is assumed for Hawaiian duck.

1.2.2 Hawaiian Stilt

The following demographic factors and assumptions (from Robinson et al. 1999 and USFWS 2005a, unless otherwise noted) were used to assess indirect take and loss of productivity of the Hawaiian stilt.

Breeding Season: The breeding season lasts from February to August each year. Hawaiian Stilt breed for two months of the year (a one month incubation period followed by parental care for one month).

Age at First Breeding: Unknown for Hawaiian Stilt, but population data suggests majority will breed age 2 but may breed as early as age 1. The subspecies black-necked stilt (*H. mexicanus mexicanus*) breeds at age 2 in Utah. The age of first breeding is assumed to be year 2.

Adults Breeding per Year: Unknown. Assumed to be 100%.

Number of broods: One though two broods have been recorded for one pair Hawaiian stilt.

Clutch Size: Clutch sizes at different wetlands on the island of O'ahu are very similar. At James Campbell NWR, the clutch sizes reported were 3.6 eggs ± 0.9 SD (range 2–7, n = 366; Coleman 1981) and 3.4±0.06 SE (n=243, Chang 1990). At Nu'upia, O'ahu, clutch size is 3.8 eggs (*n* = 47; Ueoka et al. 1976). An average clutch size of 3.6 is used in this instance.

Reproductive Success: Chicks hatched/nest for Hawaiian stilts is 2.18 chicks ± 1.6 SD (n = 982; compiled from years of USFWS monitoring) and Hawaiian stilt fledging success (number of fledglings per brood) is 0.934 fledglings ± 0.431 SD (weighted mean across 4 yr, 1985–1988, range 0.125–1.355, *n* = 131). For the purposes of the HCP, it is assumed that breeding adults will average 0.9 chicks per breeding pair..

Survival to Breeding Age: From two Hawaiian stilt cohorts, first year survival was 0.53 and 0.60; survival from first to second year for one cohort was 0.81 (Reed et al. 1998). Assuming breeding starts in the second year for most Hawaiian stilt, the survival of fledglings to breeding age is (0.6 x 0.81) 48.6%. For the purposes of this HCP, it is assumed that survival to breeding age is 50%.

Relative Productivity of Males vs. Females

Hawaiian stilt nests are incubated 95% of the time, and sexes equally likely to be incubating at any time (Coleman 1981). Feeding of young has never been observed in the wild, and young stilts survive in captivity with-out parents (Coleman 1981).

For the purposes of estimating lost productivity and indirect take it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

Sex ratio: Studies indicate the Hawaiian stilt have a balanced sex ratio..

1.2.3 Hawaiian Coot

Adjustments to the take of Hawaiian coot to account for lost productivity were developed based on the Hawaiian coot demographic factors and assumptions (Chang 1990 and USFWS 2005a, unless otherwise noted) and when not available, information from the American coot was used (Brisbin et al. 2002):

Breeding Season: Nesting occurs year round and the peak breeding season lasts from March to September each year. Breeding lasts approximately four months, with a one month incubation period followed by parental care for three months.

Age at First Breeding: Unknown for Hawaiian coot but the closely related American coot breeds at age 1 though many yearlings remain unpaired.

Adults Breeding per Year: Unknown. Assumed to be 100%.

Number of Broods: No data exits for the Hawaiian coot. The American coot typically has one brood per year, or occasionally two. It is assumed here that the Hawaiian coot has one brood per year.

Clutch Size: Clutch sizes of Hawaiian coot at James Campbell Wildlife Refuge on O'ahu average 4.9 eggs ± 0.31 SE (n = 138). Byrd et al. (1985) reported a clutch size ranging from 3 to 10 eggs, with an average of 5 eggs.

Reproductive Success: Chicks hatched/nest for Hawaiian coots is 3.2 chicks ± 0.22 SD (n = 136, 67% hatching success) and Hawaiian coot fledging success (number of fledglings per brood) is 28% (35 chicks fledged out of a total of 127). Thus it is assumed that breeding adults will average 0.9 chicks per breeding pair (=3.2*0.28).

Survival to Breeding Age: No data for Hawaiian coot. For the American coot found west of Ontario and Mississippi River survival averaged 44% for juveniles. For the purposes this HCP, it is assumed that survival to breeding age is 50%.

Relative Productivity of Males vs. Females
No information exists for the Hawaiian coot. For the American coot, brood platforms are built almost exclusively by males. Although female may incubate at night early during laying period, after 3 or 4 eggs have been laid, male usually takes major share of incubation duties. The female relieves the male at dawn and both make and female have incubation shifts. Both parents help with the hatching process by removing vitelline membranes and eggshells from the nest. The young are intensively guarded and cared for by one or both parents at all times. Both parents also share in the feeding of young (Brisbin et al. 2002).

For the purposes of estimating lost productivity and indirect take, it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

Sex Ratio: No data currently is available for the Hawaiian coot and the sex ratio is assumed to be 1:1.

1.2.4 Hawaiian Moorhen

The following demographic factors and assumptions (Chang 1990, Bannor and Kiviat 2002, and USFWS 2005a, unless otherwise noted) were used to account for indirect loss and loss of productivity of the common moorhen:

Breeding Season: Nesting occurs year round and the peak breeding season lasts from March to August each year. Each breeding period lasts approximately three and a half months, with a one month incubation period followed by parental care for two and a half months.

Age at First Breeding: The common moorhen breeds at age one.

Adults Breeding per Year: Unknown. Assumed to be 100%.

Number of Broods: Nagata (1983) reported one and likely two broods per year for common moorhens on O'ahu. Two broods per year is assumed.

Clutch Size: Clutch sizes of the common moorhen at James Campbell Wildlife Refuge on O'ahu average 4.9 eggs ± 0.13 SE (n = 87). Nagata (1983) reported clutch sizes of 6.2 eggs ± 1.76 SE in lotus fields on a marsh and lotus farms on O'ahu. Banko (1987) reported an average clutch size of 5.6 eggs (n=64) over a period of five years (1975-1980) on wetlands at Hanalei National Wildlife Refuge, Kaua'i. Polhemus and Smith (2005) report a clutch size of 5.2 eggs per clutch (range 3-7) for the Hamakua Marsh State Wildlife Sanctuary in 2004. An average clutch size of 5.3 eggs is used.

Reproductive Success: Chicks hatched/nest for common moorhen is 3.2 chicks ± 0.22 SD (n = 136, 47% hatching success) and common moorhen fledging success (number of fledglings per brood) is 42% (28 chicks fledged out of a total of 67). Thus it is assumed that breeding adults will average 1.3 chicks per breeding pair (=3.2*0.48).

Survival to Breeding Age: No data for the common moorhen or related moorhens. As moorhens (Family Rallidae, Genus *Gallinule*) are closely allied to coots (Family Rallidae, Genus *Fulica*), particularly the American coot (Nagata 1983), the survival rate for the American coot is thus also used for the common moorhen. The American coot found west of Ontario and Mississippi River has a survival rate that averages 44% for juveniles. For the purposes of this HCP, it is assumed that survival to breeding age for the common moorhen is 50%.

Relative Productivity of Males vs. Females

Typically, common moorhen are monogamous and a single breeding pair defends a breeding territory. Both sexes participate in construction and maintenance of nests. Males reportedly do most of the collecting of materials, while females do most of the arranging of materials at the nest site. Both sexes incubate. Cooperative nesting, where two or more females share a mate as well as a nest has not been reported for the common moorhen in Hawaii.

For the purposes of estimating lost productivity and indirect take, it is assumed that males and females each contribute 50% towards indirect take and the average annual productivity.

Sex ratio: The sex ratio of common moorhen in Cambridgeshire, United Kingdom is 1:1 (McRae 1996)

1.3 Hawaiian Short-eared Owl

Very little life history information is available for the Hawaiian short-eared owl. The demographic factors for the short-eared owl (*Asio flammeus flammeus*) are used instead (Wiggins et al. 2006) unless otherwise noted. The following demographic factors and assumptions were used to account for indirect take and loss of productivity of the Hawaiian short-eared owl:

Breeding Season: Nesting occurs year round. The breeding period lasts approximately two months (nesting and incubation).

Age at First Breeding: The short-eared owl breeds at age one.

Adults Breeding/Year: Unknown and assumed to be 100%

Reproductive Success: Reproductive success of short-eared owl is highly variable and closely linked to food availability and predation. The mean clutch size for North America is 5.6 (range 1–11, n = 186). Thus it is assumed that breeding adults will average 5.6 chicks per breeding pair.

Survival to Breeding Age: No data is available for the survival rates of juveniles of short-eared owls. Burrowing owls (*Athene cunicularia*) have a survival rate of 19% in Florida, 30% in California and 57% in North Dakota (Haug et al. 1993, Davies and Restani 2006). Barn owls (*Tyto alba*) also have very low survival rate with only 25-35% of barn owls surviving to year one in the north temperate regions (Marti et al 2005). Data from burrowing owls were chosen because as a species, they are ground nesters like the Hawaiian short eared owl and barn owls are known to live in similar habitat as short-eared owl both on the North American continent and in Hawaii. Both burrowing owl and barn owl also mature at age one like the short-eared owl, thus juvenile mortality measurements are more likely to be comparable. To provide additional benefit to the species, Hawaiian short-eared owl survival is estimated to be 40%.

Number of Broods: One, though double brooding has been recorded.

Clutch Size: The average clutch size of the short-eared owl in North America is 5.6 (range 1-11).

Pair Productivity: Based on the above demographics and assumptions, the average annual productivity (*i.e.*, annual production of breeding age adults) of an adult pair is estimated as follows (from Kaheawa Wind Power, LLC 2006):

Relative Productivity of Males vs. Females: Males and females contribute equally to parental care of the nestlings. While the female builds the nest and broods, the male feeds the female and defends the nest. The male also provided food for the female to feed to the nestlings.

For the purposes of estimating lost productivity it is assumed that males and females each contribute 50% to the average annual productivity.

Sex Ratio: The sex ratio of the short-eared owl is likely 1:1. The sex ratio reported by Arroyo et al (2000) is 9:12 of 21 nestlings examined. The results were however not significantly different from unity.

1.4 Hawaiian Hoary Bat

Little life history information exists for the hoary bat (*Lasiurus cinereus cinereus*) found on continental America. Because these bats are migratory, do not hibernate and are not colonial, they are difficult to study. Even less life history information is available for the Hawaiian hoary bat. Hence, adjustments to the take of the Hawaiian hoary bat to account for lost productivity were developed based on the following demographic factors and assumptions using information from the hoary bat from continental America or other bat species when necessary:

Breeding Season: The pregnancy and lactating period for the female Hawaiian hoary bat occurs from April to Augustr each year. The breeding lasts approximately four months, with a three month gestation period followed by parental care of one month (NatureServe 2008).

Age at First Breeding: Hoary bats on the continental US breed at age one (Gannon 2003, Koehler and Barclay 2000)

Adults Breeding/Year: Estimated at 100% for colonial bats (Gannon 2003), no data available for the hoary bat. Adults beeding/year is assumed to be 100 % for the Hawaiian hoary bat for purposes of this HCP.

Reproductive Success: A study following young of the hoary bat in Manitoba, Canada records that 23 out of 25 young fledged, resulting in a reproductive success of 92% (Koehler and Barclay 2000). Reproductive success is typically high for bats as they have a life history strategy where they have few young, low reproductive rates and are long lived compared to mammals of equivalent size (Kunz et al. 2005).

Survival to breeding age: No data exists for the Hawaiian hoary bat or the hoary bat on the American continent. However, survival is low for female little brown bats (*Myotis lucifugus* 20.4-47.2%) and female big brown bats (*Eptesicus fuscus,* 10.5-31.9%, Humphrey 1982). Survival rates of Hawaiian hoary bats probably approximate those of the big brown bat more closely than the little brown bat, given that they similar life history strategies such foliage roosting and the ability to commonly have two young at a time. The survival rate of Hawaiian hoary bats is estimated to be 30%.

Number of Broods: One per year.

Litter Size: Both Bogan (1972) and Koehler and Barclay (2000) in separate observations record that 6 females located before parturation gave birth to a total of 11 young, resulting in an average litter size of 1.83. Thus it is assumed that breeding adults will average 1.8 juveniles per breeding pair.

Relative Productivity of Males vs. Females: Male hoary bats only contribute sperm to the breeding process. Females are solely responsible caring and feeding the young till fledging. For the purposes of estimating inidirect take, it is assumed that males contribute nothing to indirect take and females 100%.

Sex Ratio: Sex ratios of Hawaiian hoary bats inferred from samples obtained during different seasons indicate that during the pre-pregnancy and breeding season (April to August), sex ratios in the lowlands are approximately 1:1. During the post-lactation period (September to December) the sex ratio of females to males in the lowlands increases to 4:1 (Menard 2001).

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Appendix 6

Wildlife Education and Observation Program

Purpose	To educate project employees and other on-site personnel in the observation, identification and treatment of wildlife
Approach	In conjunction with regular assigned duties, all personnel will: ⅄ attend wildlife education briefings conducted in cooperation with DOFAW and USFWS; ⅄ monitor wildlife activity while on the site; ⅄ identify key species when possible (Hawaiian Petrel, Newell's Shearwater, Hawaiian duck, Hawaiian stilt, Hawaiian coot, Hawaiian moorhen and Hawaiian Hoary Bat); ⅄ document specific observations with the filing of a Wildlife Observation Form; ⅄ identify, report and handle any downed wildlife in accordance with the Downed Wildlife Protocol, including filing a Downed Wildlife Monitoring Form – Incidence Report; ⅄ respond and treat wildlife appropriately under all circumstances.
Notes	All personnel will avoid approaching any wildlife other than downed wildlife; avoid any behavior that would startle or harass any wildlife; and not feed any wildlife.

Descriptions and Photographs
Follow

Hawaiian Petrel	
Description	16 inches, 36-inch wingspan. Head, wings and tail are sooty-colored, contrasting with slightly paler back. Forehead and underparts are white; tail is short. Feet are bi-colored pink and black. Downy chicks are charcoal gray.
Voice	Distinctive call heard at breeding colonies is a repeated moaning "ooh-ah-ooh." At their burrows, birds also produce a variety of yaps, barks and squeals.
Habits	The Hawaiian Petrel is generally seen close to the main Hawaiian islands during breeding season; otherwise, it is a pelagic species. The flight is characterized by high, steeply-banked arcs and glides; the wings are long and narrow. Breeding extends from March to October. One white egg is laid within deep burrows or under rocks. Adults arrive in colonies well after dark. As the chicks develop, parental care becomes less frequent and adults leave the colony each year two to three weeks before the chicks. Adults feed on squid, fish and crustaceans, and pass food to chicks by regurgitation. Predation by introduced rats, cats and mongooses is a serious threat to this species.

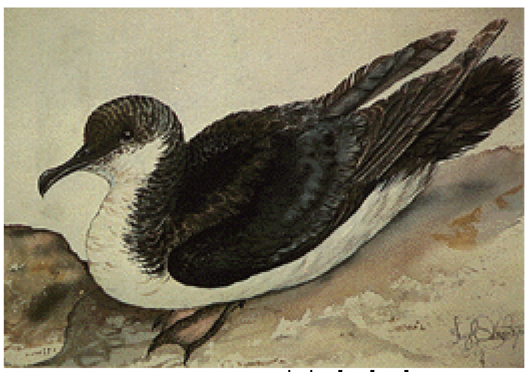
HNP/C. Hodges

HVNP/W Banko

source: http://pacificislands.fws.gov/wesa/uau.html

source: http://www.birdinghawaii.co.uk/xHawaiianPetrel2.htm

Newell’s Shearwater	
Description	12 – 14 inches, 30 – 35-inch wingspan. Black above and white below. The white extends from the throat to the black undertail coverts. Sharp contrast of dorsal/ventral color is more distinct than in larger, more common Wedge-tailed Shearwater. Bill, legs and toes are dark; webbing between toes is pink.
Voice	Around nesting colony, a variable, jackass-like braying and crow-like calling.
Habits	The flight of the Newell’s Shearwater is characterized by rapid, stiff wingbeats and short glides. This species occurs in Hawaiian waters during the breeding season (April to November); it flies to nesting colonies only after dark, departing before dawn. Birds are highly vulnerable to predation by rats and cats. Many fledglings departing the colonies in late fall are attracted to urban lights and fall on highways or other brightly-lit areas.



Painting by Sheryl Ives Boynton

source: http://pacificislands.fws.gov/wesa/ao.html

source: http://audubon2.org/webapp/watchlist/viewSpecies.jsp?id=141

source: http://www.birdinghawaii.co.uk/XNewells2.htm

Hawaiian Stilt	
Description	16 inches, both sexes are visually similar; extension of black around eyes and head, traveling down sides of neck. Long, pink legs; black bill. Males have a glossy black back while female backs are tinged with brown. Chicks are downy and tan with black speckling. Immature stilts have similar coloring as the North American breed, with a brownish back and a white cheek patch.
Voice	When disturbed in flight or on the ground, a loud, sharp "kik-kik-kik" call is heard. While resting, stilts may voice a soft, muted call. Immature birds give a distinct peeping call.
Habits	The Black-Necked Stilt can be found singly, in pairs or groups in wetland habitat, usually marshy areas, mudflats, and ponds. They nest in loose colonies close to the water on mudflats. Shallow depressions lined with twigs, stones, and other debris are used as nesting areas. Stilts consume fish, worms, aquatic insects, and crabs. The standard clutch is four eggs. Hatchlings will leave the nest to feed with the adults. Aggressive defenders of their territories, adults often feign injury as a distraction for predators that are near nesting sites and offspring.

source: http://en.wikipedia.org/wiki/Image:Black-necked_Stilt.jpg *source: http://en.wikipedia.org/wiki/Image:Bnstiltpair.jpg*

Hawaiian Duck or Koloa Maoli	
Description	Males are 19-20” in length while females are slightly smaller at 16-17”. Although both sexes have a mottled brown coloring, males have darker heads and necks with bright orange feet and olive colored bills. Females have bills that are more orange and their feet are a dull orange. The secondary wing feathers of the koloa maoli are greenish-blue, with white borders.
Voice	The koloa has a quack like a mallard, but are quieter and less vocal.
Habits	Generally found in wetland habitats such as river valleys and mountain streams, the Hawaiian duck are usually seen in pairs. Clutches are from two to ten eggs with in incubation period of less than 30 days. Nests are commonly on the ground and near water.

Source: http://en.wikipedia.org/wiki/File:Hawaiian_duck.jpg

Hawaiian Coot or ‘Alae Ke’oke’o	
Description	This small waterbird measures 14” in length for both male and female. Other similarities between sexes include a pointed white bill and bulbous frontal shield. The body color of adult birds are slate gray with white undertail feathers; feet are lobed instead of webbed and are greenish-gray.
Voice	Calls are scratchy clucking noises and include a variety of short, harsh croaks.
Habits	Their environment consists of brackish and freshwater marshes and ponds. Hawaiian coots feed on tadpoles, insects, fish as well as the seeds and leaves of aquatic plants. Nesting usually occurs between March and September with the construction of a floating nest on wetland vegetation using aquatic plants. Four to ten eggs are laid. Chicks are capable of swimming shortly after hatching.

Source: http://en.wikipedia.org/wiki/File:Fulica_alai.jpg

Common Moorhen or 'Alae 'Ula	
Description	Endemic to the islands of Oahu, Kauai and Molokai, both sexes measure 13" in length and are slate-gray in color and darker gray on the head and neck. This waterbird has a white streak on its' flanks, a white undertail and the frontal shield and base of bill are red with yellow at the tip of the bill. Adolescent moorhens are olive brown to grayish brown in color with a brown or pale yellow bill.
Voice	The 'alae 'ula emit cackling calls and croaks similar to that of a chicken and higher in pitch than the coot.
Habits	The common moorhen can be found in freshwater marshes, wet pastures, wetland agricultural areas, reservoirs, and reedy margins of water courses. This species are able to sustain themselves on aquatic insects, mollusks, grasses, water plants, and algae. Six to nine eggs are found in the nest which is often built on folded reeds.

source: http://upload.wikimedia.org/wikipedia/commons/2/2b/Kokoszka%28Grzecho_Lukasik%29.jpg

Short-Eared Owl	
Description	Buffy brown plumage with dark streaks on the chest, abdomen, and back. Females are darker in color than males. 13-17 inches in length; female wingspan is 107cm while male wingspan is105cm. Eyes are yellow and circled with black and set in buffy white facial disks which are surrounded with a brown ring. Their feet and legs are feathered.
Voice	Generally quiet creatures; their call is similar to a muffled bark. During courtship, low hoots will be accompanied by loud yapping and wing clapping. If excited near the nest, both sexes squeal, bark, hiss, and squawk.
Habits	At dawn and dusk, the Short-Eared Owl is active. They hunt mainly at night and during the morning and late afternoon searching for insects, rodents, and other birds. Nests are built on the ground; normally a clutch of three to six white eggs are laid. Prey is usually carried in their talons as opposed to their beak.

source: http://en.wikipedia.org/wiki/File:Asio-flammeus-001.jpg

Hawaiian Hoary Bat	
Description	Weighs 5 to 8 ounces, has a 10.5 – 13.5-inch wingspan. Females are larger than males. It has a heavy fur coat that is brown and gray, and ears tinged with white, giving it a frosted or "hoary" look.
Voice	Like most insectivorous bats, this bat emits high frequency (ultrasonic) echolocation calls that detect its flying prey. These calls generally range from 15 – 30 KHz. Their lower frequency social calls may be audible to humans. The low frequency “chirps” are used to warn other bats away from their feeding territory.
Habits	The Hawaiian Hoary Bat is nocturnal to crepuscular and eats insects. Little is known about its biology, distribution, or habitat use on the Hawaiian islands, though it is thought to be most abundant on the Big Island. It occurs primarily below 4,000 feet elevation, although it commonly is seen at 7,000 to 8,000 feet on Hawai`i and at 10,000 feet on Haleakala. On Maui, this bat is believed to primarily occur in moist, forested areas. In spite of this preference, though, it has been seen in Lahaina and near Mopua, both of which are dry, and on the dry, treeless crest of Haleakala. During the day, this bat roosts in a variety of tree species and occasionally in rock crevices and buildings; it even has been recorded hanging from wire fences on Kaua`i and has been seen leaving and entering caves and lava tubes on Hawai`i.

source:
http://pacificislands.fws.gov/wesa/hrybatindex.html

source:
http://www.honoluluzoo.org/hawaiian_bat.htm

Wildlife Education and Observation Program
Kahuku Wind Power
Observation Form

Observer's Name:			**Date:**	
Temperature:	**Wind Direction:**	**Wind Speed:**	**Precipitation:**	**Cloud Cover:**

Species Observed	
Location	
Proximity to Turbine	
Approximate Altitude	
Direction Traveling	
Other Species in Area	
Comments	

Appendix 7

Kahuku Wind Power Post-Construction Monitoring Protocol

Sampling to estimate the mortality occurring at a wind energy facility must consider spatial and temporal factors at different scales. At the scale of the individual turbine, the area searched should encompass the majority of where expected mortalities will fall; in addition, the search interval has to be of a frequency where most carcasses will be discovered before they are scavenged. When spatial and temporal variation within a site are considered, individual turbines within a site should be sampled sufficiently to account for the spatial variation that exists among turbines, as well as across seasons of the year when species of interest are at the greatest risk of turbine collision.

The accuracy of a mortality estimate itself depends on several factors. The probability of finding a carcass depends on the search interval and scavenging rates at the site. Scavenging rates are typically estimated by conducting trials to yield representative carcass retention times and search intervals are then adjusted accordingly. Another factor that determines the probability of finding a carcass is searcher efficiency. Searcher efficiency will account for individuals that may be killed by collision with project components but that are not found by searchers for various reasons, such as vegetation cover.

This monitoring protocol outlines the scavenger and searcher efficiency trials that Kahuku Wind Power will conduct as well as the search methods that will be used to locate carcasses impacted by the operation of the wind facility.

EARLY POST-CONSTRUCTION STUDIES

The field methods proposed below are based primarily on a refinement of the methods that have been used at Kaheawa Wind Power (KWP) on Maui since operations began in June 2006 (Kaheawa Wind Power 2006). Other recent studies of bird and bat fatalities at wind power projects in the U.S. and Europe were also reviewed to develop and refine previously-approved methods and search techniques (e.g., Kerns and Kerlinger 2004, Pennsylvania Game Commission 2007, Stantec 2008, Stantec 2009, Arnett 2005, Jain et al. 2007, Fiedler et al. 2007).

The initial period of fatality monitoring at Kahuku Wind Power will entail frequent, systematic searches of the area beneath each turbine by trained technicians. Carcass removal and searcher efficiency trials will be conducted within this period. Subsequently, systematic sampling at a pre-determined reduced effort will be conducted for one year at 5-year intervals with attendant SEEF trials and carcass removal trials. A regular rapid assessment technique will be developed for the interim years to determine direct take occurring between years of systematic monitoring.

<u>Factors Considered for Scavenger and Searcher Efficiency (SEEF) Trials</u>

Factors that may affect the results of scavenger and SEEF trials include seasonal differences, vegetation types and carcass sizes. All scavenger and SEEF trials will be conducted in accordance with DOFAW monitoring guidelines.

Seasonal differences are presumed to affect the outcome of carcass removal trials. The rate of carcass retention may vary due to seasonal changes in density of predators on site, or seasonal changes in predator behavior. For the monitoring protocol at Kahuku Wind Power, the year is divided into two seasons, the winter/spring season (December – May) and summer/fall (June – November). Results from carcass removal trials may vary with season, as they are known to at KWP (Kaheawa Wind Power 2008) but the outcome of SEEF trials are not expected to vary with season.

Search plots will be mowed monthly and maintained throughout the life of the project. For this reason, scavenger and SEEF trials are not expected to vary with vegetation type.

Carcass sizes will also likely affect the outcome of both scavenger and SEEF trials. Three size classes have been established to reflect the size classes of the Covered Species: bat size, medium birds (waterbirds) and large birds (seabirds, owl). Based on studies conducted at KWP and elsewhere, it is expected that as size increases, both carcass retention times and searcher efficiency will increase.

<u>Placement of Carcasses for Searcher Efficiency and Carcass Removal Trials</u>

Each carcass used in searcher efficiency or carcass removal trials will be placed randomly within the search plots. These points will be generated within each identified vegetation zone using ArcView 9x with the Generate Random Points tool in Hawth's Analysis Tools 3.27. Parameters that will be specified for each randomly chosen location will include the minimum distance between random points. Minimum distances between random points will ensure that carcasses are not placed too close together. This will maintain the independence of the samples and prevent predator swamping. These points will subsequently be loaded into a GPS as waypoints to allow the accurate placement of the carcasses.

<u>Carcass Removal Trials</u>

The objective of performing carcass removal studies at Kahuku Wind Power will be to determine the average amount of time an avian or bat carcass remains visible to searchers before being removed by scavengers or otherwise rendered undetectable. Trials will be conducted at Kahuku Wind Power with the purpose of maintaining an ongoing record of scavenging rates at different times of year, that will best reflect site-specific conditions in the event that a take does occur. Eight to twelve carcass removal trials will be conducted during the initial survey year, designed to enable four to six trials within a corresponding season (summer/fall and winter/spring). These trials will be used to adjust the number of estimated direct takes of Covered Species observed by correcting for carcass removal bias.

Each carcass removal trial will consist of placing a pre-determined number of carcasses (up to a maximum of seven specimens) of varying size classes on the ground at random locations within search plots. The carcass will be placed such that it approximates what would be expected if a bird/bat came to rest on the ground after having collided with an overhead structure. The intent will be to distribute trials within the project area to represent a range of habitat conditions and seasonal variability. Fresh carcasses will be used whenever available, if frozen carcasses are used, all carcasses will be thawed before being deployed. An example of a possible sampling design is presented in Table 1.

All carcasses will be checked daily for up to 30 days, or until all evidence of the carcass is absent. On day 30, all remaining materials, feathers or parts will be retrieved and properly discarded. Results of trials provide a basis for determining the search frequency necessary to ensure that birds and bats are not scavenged before they can be detected by searchers (see Barrios and Rodriguez 2004 and Kaheawa Wind Power 2008). In some instances, carcasses may be monitored beyond the 30 day survey duration if the information being gathered substantially informs the conclusions of the monitoring exercise. Data will be analyzed by season, and carcass size classifications.

Table 1. Possible Sampling Scheme for Kahuku Wind Power Carcass removal trials for One Season

Size class	Season	Vegetation	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Total sample size
Bats	Winter / Spring	Mowed grass	4		4		4		12
Medium Birds	Winter / Spring	Mowed grass	3		3		3		9
Large Birds	Winter / Spring	Mowed grass		3		3		3	9
		Total	7	3	7	3	7	3	30

Searcher Efficiency Trials (SEEF)

As with SEEF trials at KWP, trials will be conducted in association with the regular search effort to estimate the percentage of avian/bat fatalities that are found by searchers. Searcher efficiency will be evaluated according to differences in carcass detection rates for different sized birds and for bats. Estimates of searcher efficiency will be used to adjust estimates of direct take by accounting for carcass detection bias.

Personnel conducting carcass searches will not be told when or where trials will be conducted. Trials will be administered during the monitoring period but dates will be chosen randomly. Each trial will consist of 3 - 7 bird carcasses and/or bats or bat surrogates. Prior to a search commencing that same day, each carcass will be placed at randomly selected locations. Each trial carcass will be discreetly marked and located by GPS so it can be relocated and identified when found. If carcasses of the Covered Species are not available, carcasses of surrogate species will be used as previously described. Data will be analyzed according to carcass size classifications. If the results between trials is highly variable, more trials will be conducted to increase statistical confidence in the resultant values and enable mean searcher detection probabilities to be ascertained for the project site.

Procurement of Carcasses for Trials

If using state or federally protected species as surrogates for trials, all state and federal laws pertaining to transport, possession, and permitted use of these species along with appropriate animal use protocols will be followed. A scientific permit will be obtained for all species that may be used in trials. The Applicant will cover all costs and responsibilities for acquiring carcasses for trials. Carcasses used in the trials will be selected to best represent the size, mass, coloration, and if possible should be closely related to or roughly the same proportions as the Covered Species. For example, Wedge-tailed shearwaters, a close taxonomic relative of the Hawaiian Petrel and Newell's Shearwater, exhibit a close resemblance to both these covered seabird species, and have been used successfully at KWP and elsewhere in carcass removal trials. All carcasses used for the trials will be fresh or freshly thawed. Dark colored mammals (e.g., small rats, mice) and small passerines (e.g. house finch, house sparrow) may be used as surrogates for bats. Other types of avian carcasses that may prove useful for trials include locally-obtained road kills, downed seabirds, owls, and waterbirds, or species not protected under the MBTA such as pheasant (*Phasianus colchicus*) and rock dove (*Columba livia*). Use of species protected under ESA or MBTA will require permission from DLNR and USFWS.

Search Intervals

Consultation with the Endangered Species Recovery Committee (ESRC) and DLNR has indicated a preference for search intervals that are equal to approximately 50% of the mean carcass removal rate. Studies at the KWP facility indicate a mean carcass removal time of 9.2 days (n = 17). While Kahuku Wind Power will be conducting its own carcass removal trials, due to an expected higher density of mongoose at Kahuku Wind Power than at KWP, an average carcass retention time of one week (seven days) is assumed for the time being. Therefore, in order to comply with the request of ESRC and DLNR and account for variability in these removal rates, search intervals of three or four days were chosen. Thus, searches will be carried out twice a week at the Kahuku Wind Power turbines. These search intervals may be adjusted to more accurately reflect seasonal carcass removal rates as carcass removal trials are conducted and data indicate appropriateness of sampling design modifications.

Should SEEF trials indicate that carcass retention times are less than 7 days, trapping may be conducted to depress scavenger populations and increase carcass retention times. All applicable permits will be obtained.

Search Areas Beneath Meteorological Towers

The search area beneath the temporary met towers will be circular and extend 10 m beyond the supporting guy wires. The search area beneath the permanent unguyed met tower (80 m) will also be circular and be half the height of the tower at 40 m search radius.

Search Areas Beneath Individual Turbines

Several studies of small-bodied animals (songbirds and bats), with adequate sample sizes (n = 69 – 466), have shown that the majority of carcasses are found within a search area of less than 50% of the maximum turbine height (Arnett 2005, Jain et al. 2007, Fiedler et al. 2007; see Fig. 1a, b, 2a, b, c, d, e). Most of the carcass distributions (% fatalities vs. distance from turbine) appear to be well described by 2nd degree polynomials, with most fatalities found at approximately 25% of the distance of turbine height, then decreasing with few fatalities occurring beyond 50% of the maximum turbine height (Fig 2a, b, c).

These data are also supported by the distribution of carcasses that have been found at the operating KWP facility. To date, after more than 3000 turbine plot searches conducted during the three years operation at KWP, only eight carcasses have been found that are clearly attributable to collisions with the turbines. The carcasses consist of one Hawaiian hoary bat, one Hawaiian petrel, three nēnē, one barn owl, one ring-necked pheasant, and one white-tailed tropicbird with distances from the turbine ranging from 2 – 73 m (2 – 81 % of maximum turbine height at 90 m). Search plots for KWP are of 90 m radius (100% turbine height) and no intact carcasses were found beyond a distance of 50% turbine height, with the exception of the white-tailed tropicbird which was found in two locations (56% and 81% maximum turbine height) in which a portion of the carcass was discovered at 81% maximum turbine height. It should not be ruled out that the material recovered in this case may have been moved by a scavenger.

Most studies have concentrated on the fatality distributions of small birds and bats. However, these fatality distributions are also expected to apply to larger bodied birds, though because of their greater weight, they will likely be found closer to the base of the turbines.

Given the considerations detailed above, it is proposed that search areas beneath individual turbines for Kahuku Wind Power will consist of a combination of sample areas including 50% and 75% maximum turbine height (64 m and 96 m, radii, respectively).

Spatial and Temporal Sampling Scheme During the First Year of Intensive Sampling

Frequency of Sampling

Sampling at Kahuku Wind Power will initially consist of twice weekly carcass searches. The actual search intervals will be adjusted based on the results of the seasonal carcass removal trials as they become available. The search intervals will be determined in consultation with DLNR and USFWS.

Temporal Sampling Scheme

The first weekly search will consist of sampling all 12 turbines with a search area radius of 50% maximum turbine height (Figure 3A). The second search of the week will consist of sampling a randomly selected subset of six turbines (Fig 3B) with a search area radius of 75% of maximum turbine height. Turbines are randomly chosen to reduce possible bias. The subsequent week, the other set of six turbines will be searched to 75% maximum turbine height (Fig. 3C). The random selection of turbines will only be done once, prior to searches commencing at the project. The same subset of turbines will then be alternated each week for the remaining duration of the intensive sampling. In essence, each turbine will be searched to 75% turbine height at 2 week intervals. As the rate of mortality for all Covered Species at Kahuku Wind Power is expected to be low, sampling all turbines twice weekly at the 50% maximum turbine height and a subsample of six with a search area radius of 75% of turbine height will ensure a high probability that most of the mortality will fall within the search areas. The short search interval at 50% maximum turbine height will also increase the probability that any carcasses will be found before they are removed by scavengers.

Plot Maintenance

All search plots will be mowed monthly out to 75% turbine height and maintained throughout the life of the project.

<u>Determining Spatial and Temporal Variation on Site</u>

The twice weekly search frequency is anticipated to accurately describe variation in mortality rates at different turbines within the site, as well as identify periods when Covered Species that potentially occur year round on site (e.g., Hawaiian short-eared owl, Hawaiian hoary bat) are at greater risk of collision. Each turbine will be sampled 108 times a year, resulting in a total of 1296 turbine searches per year for the entire facility.

<u>Intensive Sampling During the Second Year</u>

Sampling intervals after the first year will be adjusted to reflect seasonal carcass retention rates measured by the carcass removal trials. In addition, if sufficient data is collected and a reliable correction factor is obtained for the search area between 50 -75% maximum turbine height, all search plots may be reduced to 50% radius. The change in sampling regime will be determined by Kahuku Wind Power in consultation with DLNR, USFWS and members of the ESRC .

However, the same sampling regime as Year 1 will be continued if data indicates that more sampling is needed before any change can be made.

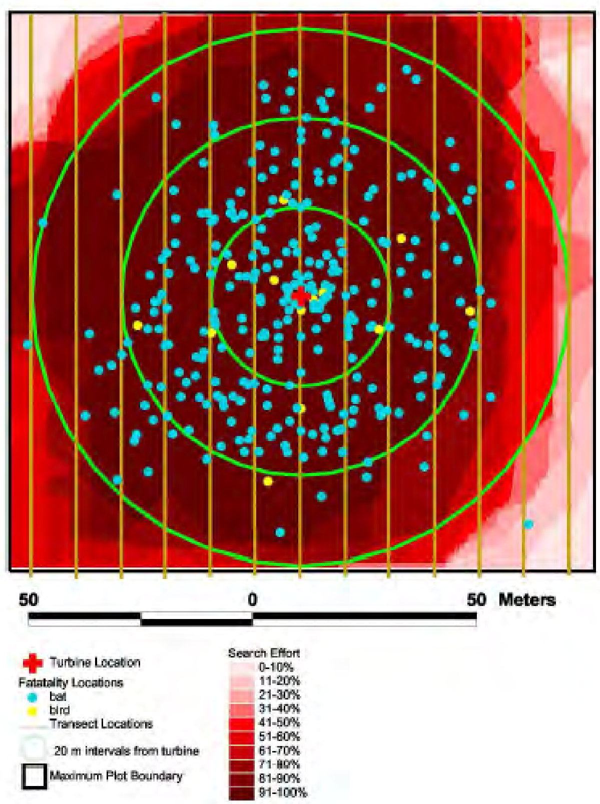


Figure 1a. Bat and bird fatalities (n=466 bats) at all turbines combined at Meyersdale Wind Energy Center in Pennsylvania, 2 August to 13 September 2004 (Arnett 2005). The maximum turbine height was 115 m.

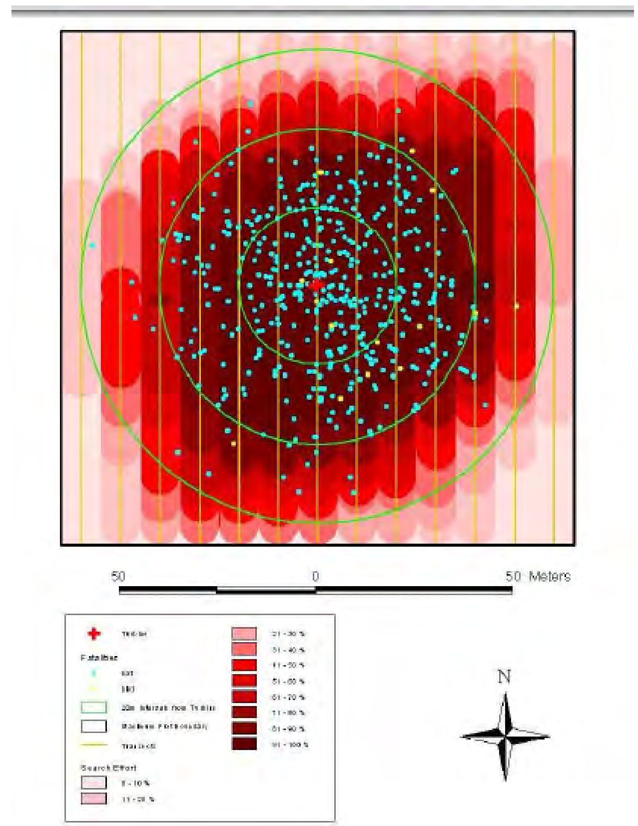
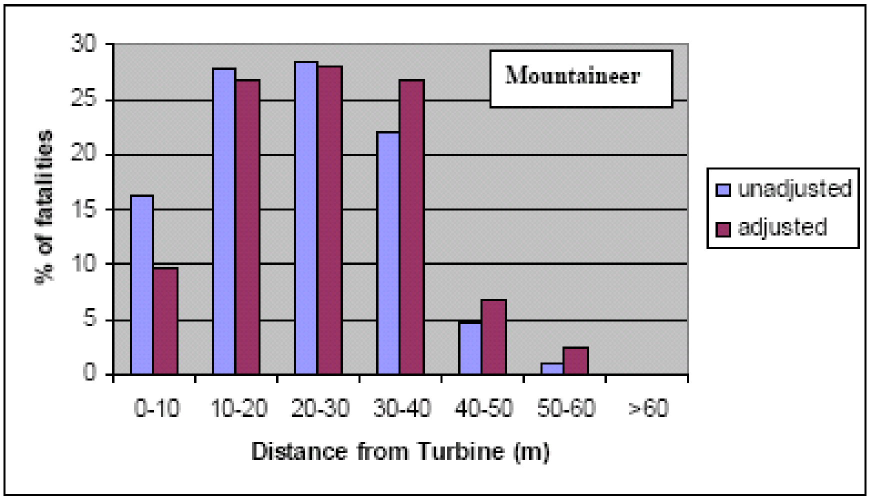
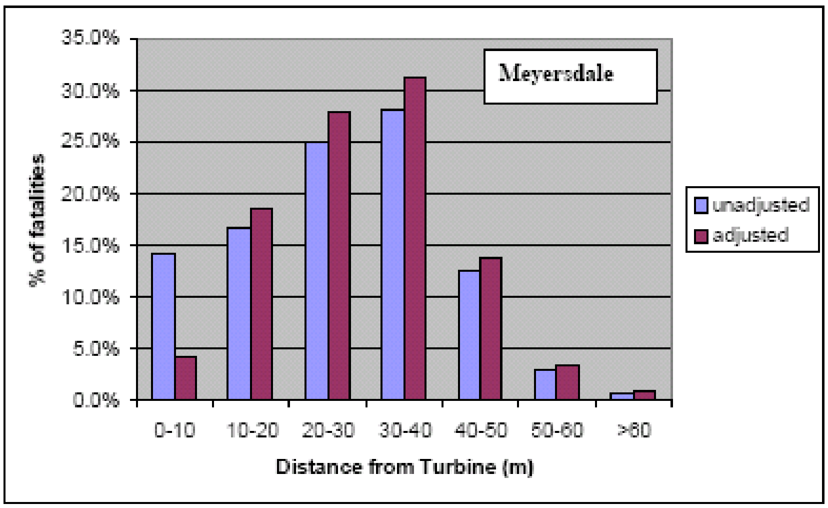


Figure 1b. Bat and bird fatalities (n=499 bats) at all turbines combined at Mountaineer Wind Energy Center in West Virginia, 31 August to 11 September 2004 (Arnett 2005). The maximum turbine height was 104.5m.

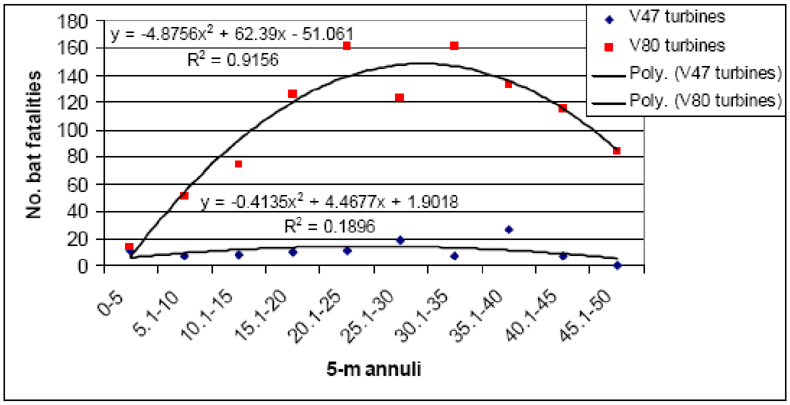


a

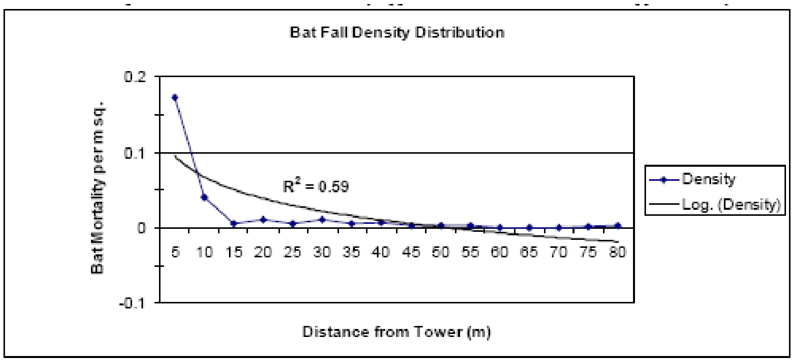


b

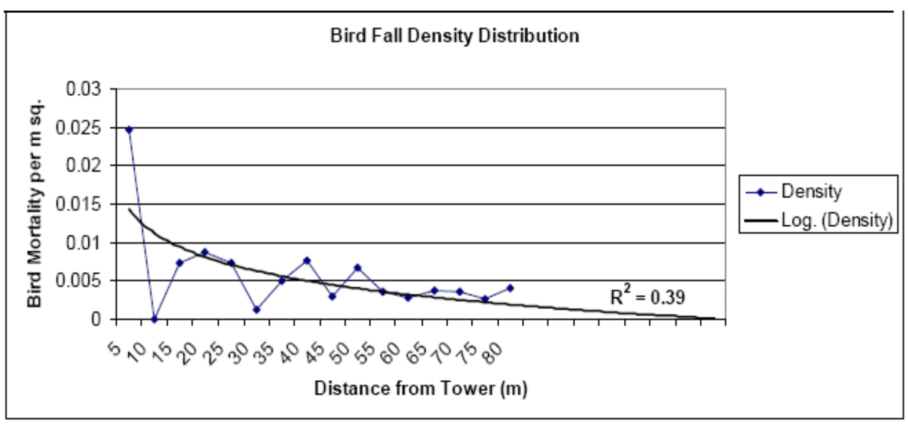
Figure 2a, b. Distribution of fatalities (birds and bats) as a function of distance from a turbine for Mountaineer and Meyersdale sites based on unadjusted counts, and counts adjusted for searcher detection and sampling effort (figures from Arnett 2005). The maximum turbine height was 104.5 m.



c



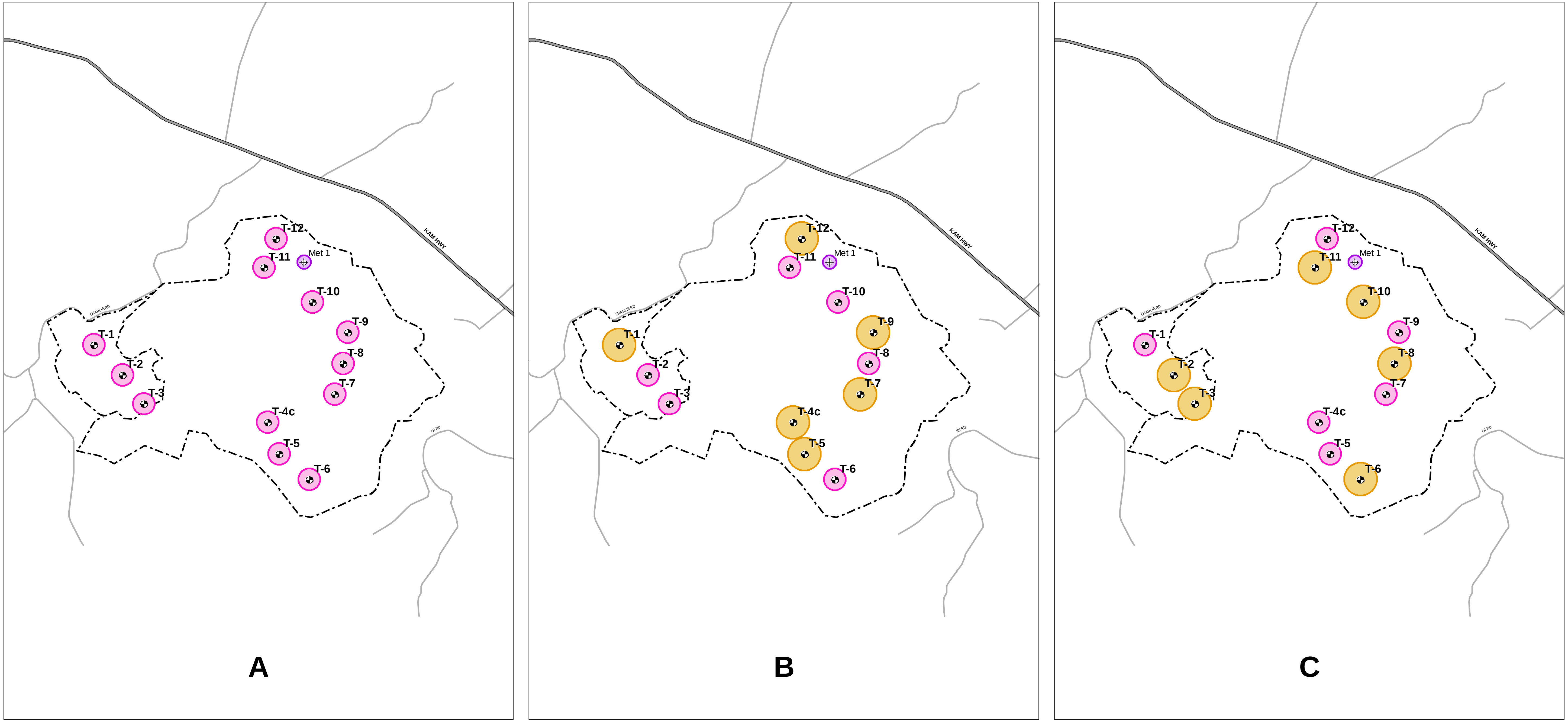
d

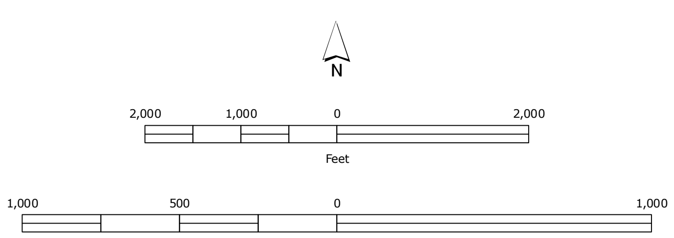


e

Figure 2c. Number of bats found within 5m annuli around V47 turbines (n = 20) and V80 turbine (n=243) from 5 April to 20 December 2005 and associated trend line for Buffalo Mountain, Tennessee (figure from Fielder et al 2007). The trend line for the V80 predicts that bat fatalities would reach zero at 59.6 m from the turbine (maximum turbine height is 120m). Data from the V47 is not considered in this report due to small sample sizes.

Figure 2d,e. Maple Ridge Wind Power, New York bat and bird fatality density distributions from September 1 to November 15, 2006, in relation to distance from towers with associated trend lines. The maximum turbine heights were 122 m (figures from Jain et al 2007). The trend lines predict that bird carcass densities approximate zero at 110m and at 45m for bats. The maximum turbine height was 122 m.





Legend

- Turbine Locations
- Met Tower
- 50 % (64 Meter Radius) Maximum Turbine Height Search Plots
- 75 % (96 Meter Radius) Maximum Turbine Height Search Plots
- Met Tower Search Areas
- Project Parcels

Fig 3 Search areas

Post Two-Year Intensive Sampling Period

Spatial and temporal trends on site should also be well understood at the end of the two-year intensive sampling period, enabling correction factors to be appropriately applied. Depending on findings, the correction factors may enable a decrease or modification of sampling effort (e.g. increase in search intervals or decrease in the number of turbines searched), identify specific turbines or times of the year when sampling effort should be concentrated, and inform adaptive management considerations. Discussion with ESRC, USFWS and DLNR has indicated a preference for the reallocation of effort whereby mitigation efforts are increased in exchange for a reduction in fatality monitoring. It is expected that the systematic monitoring effort will be scaled back by about 50%. It is also proposed that systematic fatality monitoring after the post two-year intensive sampling period be conducted at the beginning of 5-year bins; years 6, 11 and 16, resulting in a total of 5 years of systematic monitoring during the life of the project (Table 2). SEEF trials and carcass removal trials will be repeated during these years to determine if any of the variables have changed over time (Table 2). All adjustments to direct take will use the most recent estimates from the SEEF and carcass removal trials.

In addition to this reduced monitoring effort, regular rapid assessment (RRA) of each search plot will be conducted in the interim years. This may consist of personnel searching each plot to 75% turbine height on an ATV (all terrain vehicle). The frequency at which the surveys take place will be determined at the conclusion of the carcass removal trials for that 5-year period. SEEF trials will also be conducted to determine the searcher efficiency of the chosen RRA method. All adjustments to direct take found in the interim years will use the estimates from the SEEF and carcass removal trials for that 5-year time period.

The systematic monitoring during the first year of the 5-year period and the subsequent 4-year rapid assessment is designed to inform the Applicant if the take is still occurring at Baseline levels or whether take has moved to a Higher or Lower tier based on 5-year and 20-year take limits outlined in the HCP. Five-year total direct take levels will be determined for each 5-year bin while 20-year total direct take levels will be a cumulative total from the start of project operation.

This long-term sampling regime will be refined by Kahuku Wind Power in consultation with ESRC, USFWS, statisticians and wind energy experts after the initial 2-year intensive sampling period.

Years

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
IM1	IM2	RRA	RRA	RRA	SM	RRA	RRA	RRA	RRA	SM	RRA	RRA	RRA	RRA	SM	RRA	RRA	RRA	RRA
SEEF trials	SEEF trials	SEEF trials			SEEF trials	SEEF trials				SEEF trials	SEEF trials				SEEF trials	SEEF trials			
CRT					CRT					CRT					CRT				
1st 5-year bin					2nd 5-year bin					3rd 5-year bin					4th 5-year bin				

IM1 = intensive monitoring for year 1; IM2 = intensive monitoring for year 2; RRA = regular rapid assessment; SM= systematic montoring
CRT= carcass removal trials

Total direct take for 1st 5-year bin = total direct take for IM1 + total direct take for IM2 + total direct take for RRA years

Total direct take for subsequent 5-year bins = total direct take for SM + total direct take for RRA years

Table 2. Timetable for SEEF and scavenger removal trials and search techniques

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Appendix 8

Funding Matrix
Kahuku Wind Power Habitat Conservation Plan

	Item/Activity	One-time Cost	Annual Cost	Years 1-5	Remaining 15 Years	20-year Permit Duration
General Measures	Short-eared owl monitoring during construction	$7,500				$7,500
	Wildlife Education and Observation Program (WEOP)		$1,500	$7,500	$25,000	$32,500
	Maximum Cost	**$7,500**		**$7,500**	**$25,000**	**$40,000**
Seabird Mitigation (Baseline)	Alt. 1 - Makamakaole fencing and social attraction option, Kahuku Wind Power portion		$50,000	$250,000	$150,000	$400,000
	Alternative 2a - management and monitoring of existing fenced burrows at HNP (assuming Hawaiian petrel mitigation on Maui and supplementing an island-wide HCP for Newell's shearwater on Kauai)		$50,000	$430,000	$250,000	$680,000
	Alternative 2b - management and monitoring of existing fenced burrows at HNP (assuming worst case of Hawaiian petrel mitigation on Maui and particiating in Newell's shearwater management project on Kauai)		$100,000	$500,000	$250,000	$750,000
	Maximum Cost		**$100,000**	**$500,000**	**$250,000**	**$750,000**
Mitigation for Higher Rates of Take	Increased mitigation efforts at the same site or mitgation at another seabird site		$25,000	$75,000	$75,000	$150,000
	Maximum Cost		**$25,000**	**$75,000**	**$75,000**	**$150,000**
Lower Rates of Take	covered by Baseline mitigation of 3 years					
Seabird Contingency Fund	**Initial Value**	**$150,000**			**Escalated Value Yr 20**	**$245,792**

	Item/Activity	One-time Cost	Annual Cost	Years 1-5	Remaining 15 Years	20-year Permit Duration
Waterbird Mitigation (Baseline)	Funding for DOFAW truck, equipment and staff for waterbird management	$14,000	$92,500	$291,500	$291,500	$597,000
	Maximum Cost	**$14,000**		**$291,500**	**$291,500**	**$597,000**
Mitigation Measures at Higher Levels of Take	Increased mitigation efforts at same site or another site				$145,750	$145,750
	Maximum Cost				**$145,750**	**$145,750**
Lower rates of take	same as baseline					
Contingency in the event Third-Party services are required (add 1x baseline)	**Maximum Cost**		**$92,500**	**$291,500**	**$291,500**	**$597,000**
Waterbird Contingency Fund	**Initial Value**	**$150,000**			**Escalated Value Yr 20**	**$245,792**
Short-eared Owl Mitigation (Baseline)	Program to support owl research and rehabilitation	$25,000				$25,000
	Funding for management	$50,000				$50,000
	Maximum Cost	**$75,000**				**$75,000**
Mitigation at Higher Levels of Take	Additional funding to support owl research and rehabilitation	$15,000				$15,000
	Additional funding for management	$30,000				$30,000
	Maximum Cost	**$45,000**				**$45,000**
Lower Rates of Take	same as baseline					
Short-eared owl Contingency Fund	**Initial Value**	**$75,000**			**Escalated Value Yr 20**	**$122,896**
Bat Mitigation (Baseline)	Funding for management	$150,000				$150,000
	Bat monitoring at Kahuku Wind Power and vicinity for 5 years		$12,500	$25,000	$37,500	$62,500
	Maximum Cost	**$150,000**	**$12,500**	**$25,000**	**$37,500**	**$212,500**
Additional Measures for Higher Rates of Take	Funding for increased management	$75,000				$75,000
	Low wind curtailment		$15,000		$225,000	$225,000
	Increased site-specific bat studies using enhanced audio-visual technologies to characterize activity levels and document bat interactions at facility		$10,000	$50,000	$50,000	$100,000
	Maximum Cost	**$75,000**	**$25,000**	**$50,000**	**$275,000**	**$400,000**
Measures for Lower Rates of Take	Same as Baseline					
Bat Contingency Fund	**Initial Value**	**$100,000**			**Escalated Value Yr 20**	**$163,861**

	Item/Activity	One-time Cost	Annual Cost	Years 1-5	Remaining 15 Years	20-year Permit Duration
Downed Wildlife Monitoring	Downed wildlife searches by trained technicians		$75,000	$180,000	$240,000	$420,000
	Searcher Efficiency Trials		$10,000	$20,000	$15,000	$35,000
	Scavenger Removal Trials		$20,000	$40,000	$15,000	$55,000
	Estimated Cost		**$105,000**	**$240,000**	**$270,000**	**$510,000**
Reporting	Annual		$7,500	$37,500	$112,500	$150,000
	Semi-Annual		$3,000	$15,000	$45,000	$60,000
	Interim		$2,500	$12,500	$37,500	$50,000
	Estimated Cost		**$13,000**	**$65,000**	**$195,000**	**$260,000**
Contingency in the event project requires Third-Party fatality monitoring and reporting (add 1x baseline)	**Estimated Cost**		**$105,000**	**$240,000**	**$270,000**	**$510,000**
State Compliance Monitoring	**Estimated Cost**		**$20,000**	**$75,000**	**$225,000**	**$300,000**
Changed Circumstances	If necessary, funding will be made available in conjunction with ongoing costs for implementation and other requirements according to the terms of the HCP.					
Estimated Project Sub-Totals		**One-time Cost**	**Annual Cost**	**Years 1-5**	**Remaining 15 Years**	**20-year Permit Duration**
	Baseline					
	Minimization and General Measures	$7,500		$7,500	$25,000	$40,000
	Seabird Mitigation			$500,000	$250,000	$750,000
	Waterbird Mitigation			$291,500	$291,500	$597,000
	Waterbird Mitigation 3rd Party Contingency			$291,500	$291,500	$597,000
	Short-eared Owl mitigation	$75,000				$75,000
	Hawaiian Hoary Bat Mitigation	$150,000		$25,000	$37,500	$212,500
	Sub-Total	**$232,500**		**$1,115,500**	**$895,500**	**$2,271,500**
	Higher					
	Seabird Mitigation			$75,000	$75,000	$150,000
	Waterbird Mitigation				$145,750	$145,750
	Short-eared Owl Mitigation	$45,000				$45,000
	Hawaiian Hoary Bat Mitigation	$75,000		$50,000	$275,000	$400,000
	Sub-Total	**$120,000**		**$125,000**	**$495,750**	**$740,750**
	Other					
	Downed Wildlife Monitoring			$240,000	$270,000	$510,000
	Reporting			$65,000	$195,000	$260,000
	Third-party Monitoring Contingency			$240,000	$270,000	$510,000
	State Compliance Monitoring			$75,000	$225,000	$300,000
	Sub-Total			**$620,000**	**$960,000**	**$1,580,000**

Contingency Funds	
Seabird Fund Fully Escalated	**$245,792**
Waterbird Fund Fully Escalated	**$245,792**
Short-eared Owl Fund Fully Escalated	**$122,896**
Hawaiian Hoary Bat Fund Fully Escalated	**$163,861**
Sub-Total	**$778,341**

Grand Total Including Maximum Cost for Baseline Mitigation	**$2,744,500**
Grand Total Baseline + Monitoring and Waterbird Contingencies	**$3,851,500**
Grand Total for Baseline + Higher Take Level of Mitigation + Monitoring and Waterbird Contingencies	**$4,592,250**
Grand Total for Baseline + Higher Take Level of Mitigation + Monitoring and Waterbird Contingencies + 4 Fully Escalated (Year 20) Mitigation Contingencies	**$5,370,591**

Appendix 9

Calculating Total Direct Take

Monitoring efforts at Kahuku Wind Power as prescribed in the Kahuku Wind Power HCP will result in identification of "observed" mortality, which is a statistical sampling of all mortality directly attributable to project operations. Identifying the total mortality (or "total direct take") requires accounting for individuals that may be killed by collision with project components but that are not found by searchers for various reasons, including heavy vegetation cover and scavenging. The calculation for estimating total direct take is:

Total Direct Take = Observed Direct Take + Unobserved Direct Take

Searcher efficiency (SEEF) trials and scavenger trials are conducted to arrive at estimates of unobserved direct take (See Appendix 2). SEEF trials measure how effective searchers are in finding carcasses within the search areas and scavenger trials measure the length of time carcasses remain in the field before being removed by scavengers. Scavenger trials are often used to determine the frequency at which turbines and met towers can be searched to maximize the likelihood of searchers detecting carcasses while maintaining a cost-effective survey schedule. Factors to be considered for SEEF trials and scavenger trials for Kahuku Wind Power include season and carcass size. As all search plots will be mowed and maintained, vegetation type is not expected to affect the results of SEEF trials and scavenger trials.

Numerous estimators have been developed for the calculation of unobserved direct take. The variables these estimators often include are SEEF, search intervals, and carcass retention rates within the search intervals. Newer estimators are frequently incremental improvements over older estimators as biases and deficiencies of each estimator become clearer as data accumulates. Kahuku Wind Power, LLC examined three estimators, Shoenfeld (2004), Jain (2007), and Huso (2008), in the development of the calculation to be used for determination of total direct take for its project.

The estimators are presented below:

Estimator by Shoenfeld (2004)

$$m = \left(\frac{N * I * C}{k * t * p}\right)\left(\frac{e^{I/t} - 1 + p}{e^{I/t} - 1}\right)$$

N= total number of turbines
I = interval between searches in days
C = total number of carcasses detected for the period of study (total direct take)
k= number of turbines sampled
t = mean carcass removal time in days
p = searcher efficiency (proportion of carcasses found)
e = natural log

Shoenfeld (2004) and its derivatives were found to bias total direct take calculations low as carcass retention rates (t) increased, particularly when search intervals (I) were small (Smallwood 2007, Huso 2008a, b). The weakness of the estimator resulted from the t/I not being a good estimate of scavenger efficiency (or proportion of carcasses remaining) and this bias also became more pronounced as searcher efficiency (p) became low (Huso 2008a, b).

Estimator by Jain (2007)

$$'C = \frac{C}{S_c \times S_e \times P_s}$$

'C = total number of carcasses for the period of study (total direct take)

C = number of carcasses found

S_c = scavenger efficiency (proportion of carcasses remaining)

S_e = searcher efficiency (proportion of carcasses found)

P_s = proportion of towers searched

Jain (2007) tried to avoid the bias present in the Shoenfeld (2004) estimator by directly incorporating scavenger efficiency or proportion of carcasses remaining (S_e) into his proposed estimator. Jain (2007) assumed that carcasses had equal probability of occurring on any day between search intervals, thus the average number of days a carcass was present was half the number of days between searches and S_e was determined empirically in scavenger trials for a specified time period (in this case half the search interval). This method proposed for determining S_e is fairly simplistic as scavenger efficiency is non-linear but approximates a logarithmic function (Smallwood 2007). Methods to estimate S_e have subsequently been improved on by Huso (2008a, b).

Estimator by Huso (2008)

$$\hat{m}_{ij} = \frac{c_{ij}}{\hat{r}_{ij}\hat{p}_{ij}\hat{e}_{ij}}$$

$\mathbf{m_{ij}}$ = estimated total direct take at turbine *i* over interval *j*

$\mathbf{c_{ii}}$ = observed direct take

$\mathbf{r_{ii}}$ = estimated proportion of carcasses remaining after scavenging

$\mathbf{p_{ii}}$ = estimated searcher efficiency (proportion of carcasses found)

$\mathbf{e_{ii}}$ = effective search interval

The recently introduced estimator by Huso (2008a, b) has several improvements over the previous two estimators. For estimating the scavenger efficiency or the proportion of carcasses remaining within a specified search interval (r_{ij}), Huso (2008a, b) accounts for the logarithmic nature of carcass removal, and also accounts for the removal of older carcasses over time while newer carcasses are being simultaneously deposited during the search interval. Huso (2008) has further developed methods to determine effective search intervals (e_{ij}) for cases where search intervals are much longer than the estimated carcass retention times (i.e. carcasses deposited early on in the search interval are 99% removed by scavengers before the subsequent search). Simulations run to determine the degree of bias for the different estimators has shown that the Huso (2008a, b) estimator is the least susceptible to bias over a wide range of values for each variable and is currently the most precise of the commonly used estimators (Huso 2008a, b).

Estimating Total Direct Take at Kahuku Wind Power

In the light of the recent improvements to estimators for calculating total direct take, Kahuku Wind Power, LLC proposes to apply the Huso (2008a, b) estimator to the monitoring protocol proposed for Kahuku Wind Power in Appendix 7. Three factors will be considered for scavenger trials and SEEF trials - season, carcass size, and vegetation type. The values obtained from the scavenger and SEEF trials will then be applied to the Huso (2008a, b) estimator using the following protocol:

1. Conduct SEEF trials for each carcass size. Calculate variances for SEEF trials for each carcass size. Conduct statistical tests to determine if searcher efficiency varies with carcass size. Pool SEEF values for carcass sizes that are not significantly different.

2. Determine mean carcass removal time for carcass size with season. Calculate variances for carcass removal time for each carcass size per season. Conduct statistical tests to determine if carcass removal rates vary with carcass size. Pool carcass removal rates for carcass sizes that are not significantly different.

3. Determine effective search interval for each carcass size for each season.

4. Apply values to Huso (2008a, b) formula for 50% and 50-75% search areas (see example).

5. The percent of direct take of birds within the 50% turbine height search area vs. the total number of birds taken within the entire searched area will also be calculated. This percentage will then be used as a correction factor and applied to determine direct take for the entire search area (0 - 75% turbine height) at such time when the search intensity is decreased and the areas beyond 50% turbine height are no longer searched. Should the sample size at the end of the intensive search period be so small that an accurate correction factor cannot be obtained, correction factors for each carcass size will be calculated based on data from other wind farms that have had similar sampling regimes and adequate sample sizes.

6. Methods to determine variances and confidence intervals for total direct take are currently being developed by M. Huso (Huso 2008a, Huso pers. comm.). When such methods become available, Kahuku Wind Power will apply confidence intervals to the estimated total direct take.

An example of using Huso (2008) to calculate total direct take of a medium-sized bird (Hawaiian petrel) for one season (Summer and Fall combined, June - November) is presented. For illustrative purposes, an observed take of five petrels within the 50% search area and one petrel in the 50-75% search area is assumed. The theoretical search protocol is as follows:

All 12 turbines on site will be searched twice weekly (approximately 4-day intervals) to 50% turbine height. 75% turbine height search areas for six turbines will be searched weekly. The remaining six turbines will be searched to 75% the following week. Thus each turbine will be searched to 75% every two weeks (14 days). Please see Appendix 7 for further details on the proposed monitoring protocol for Kahuku Wind Power.

Example of Calculation of Direct Take Using Huso (2009) for Hawaiian Petrel in Summer

Main equation

$$\hat{m}_{ij} = \frac{c_{ij}}{\hat{r}_{ij}\hat{p}_{ij}\hat{e}_{ij}}$$

Eq 1

$$If\ \ f(x) = \lambda e^{-\lambda x};\ S(x) = e^{-\lambda x}$$

Eq 2

$$d_{99} = \min(\ x : S(x) = 0.01, I),\ \hat{e} = \frac{d_{99}}{I}$$

Eq 3

$$\hat{\lambda} = 1 / \bar{t};$$

Eq 4

$$\hat{r} = \frac{\int_0^{d_{99}} e^{-\lambda x} dx}{d_{99}} = \frac{(1 - e^{-\lambda d_{99}})}{\lambda d_{99}}$$

m_{ij}	estimated mortality
r_{ij}	estimated proportion of carcasses remaining after scavenging
p_{ij}	estimated searcher efficiency
c_{ij}	observed take
I	search interval
e_{ij}	effective search interval
d_{99}	days to 99% of carcasses removed
t	mean carcass retention time (scavengers)

Example of Calculation of Direct Take Using Huso (2009) for Hawaiian Petrel in Summer

Season **Summer**

Search area **Vegetation type**	**50% turbine height** **Mowed grass**	**75% turbine height** **Mowed grass**
Petrel Size (SEEF) likelihood of detection (p_{ij})	0.90	0.90
Mean Carcass removal time (t) (days)	10	10
No of carcasses (c_{ij})	5	1
λ (Eq3)	0.10	0.10
d_{99}	46.05	46.05
I	4	14
d_{99} (Eq 2 applied)	4	14
e_{ij}	1	1
Eq4		
λd_{99}	0.40	1.40
r_{ij}	0.82	0.54
m_{ij}	6.74	2.06
total mortality	**8.8**	
Correction factor	**0.3**	

References:

Huso M. 2008a. Estimators of wildlife fatality: a critical examination of methods in Proceedings of the NWCC Wind Wildlife Research Meeting VII. Milwaukee, WI October 28-29, 2008. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by RESOLVE, Inc., Washington, DC, Susan Savitt Schwartz, ed. 116 pp

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Shoenfeld, P. 2004. Suggestions regarding avian mortality extrapolation. Prepared for the Mountaineer Wind Energy Center Technical Review Committee

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Appendix 10

BIOLOGICAL RESOURCES SURVEY

for the

KAHUKU WIND POWER PROJECT

KAHUKU, OAHU, HAWAII

by

Robert W. Hobdy
Environmental Consultant
Kokomo, Maui
July 2009

Prepared for: First Wind Energy, LLC

BIOLOGICAL RESOURCES SURVEY
KAHUKU WIND POWER PROJECT

INTRODUCTION

The Kahuku Wind Power project lies on 68.5 acres of land west of Kahuku Town in the foothills of the northwest Koolau Range. The parcel (Lot 1192 – TMK 5-6-05:14) is surrounded on all sides by undeveloped lands above Kamehameha Highway. This biological study was initiated in fulfillment of environmental requirements of the planning process.

SITE DESCRIPTION

The project area lies on sloping land between elevations of 240 feet and 400 feet above sea level. It borders a military access road on its north edge. Vegetation consists of a broad array of dry grasses, brush and scattered trees. Soils are silty clays of the Kemo'o, Paumalu, and Lahaina series, and used to support sugar cane agriculture. Rainfall averages 45 to 50 inches per year with a winter maximum.

BIOLOGICAL HISTORY

In pre-contact times the lower, more gently sloping lands would have been extensively farmed by a large Hawaiian population that lived in the lower valleys and along the sea shore. The ridges would have been covered by a dense tangle of native shrubs such as ‘ülei (*Osteomeles anthyllidifolia*), ‘akia (*Wikstroemia oahuensis*), ‘iliahi alo'e (*Santalum ellipticum*) and ‘uhaloa (*Waltheria indica*).

In the late 1800s much of the area was converted to sugar cane agriculature. The land was cleared, plowed, burned and harvested in continuous cycles for about 100 years. Much of the steeper land was used to pasture plantation horses and mules. This reduced the numbers and diversity of native plants considerably. Sugar was discontinued in the 1980's and the land was put into cattle grazing or left idle. Today the area is a largely non-native shrubland and forest consisting of a diverse array of aggressive weedy species and a few tough and persistent native plants that have been able to compete and survive.

SURVEY OBJECTIVES

This report summarizes the findings of a flora and fauna survey of the proposed Kahuku Windfarm Project which was conducted during July, 2009.
The objectives of the survey were to:

1. Document what plant, bird and mammal species occur on the property or may likely occur in the existing habitat.

2. Document the status and abundance of each species.

3. Determine the presence or likely occurrence of any native flora and fauna, particularly any that are Federally listed as Threatened or Endangered. If such occur, identify what features of the habitat may be essential for these species.

4. Determine if the project area contains any special habitats which if lost or altered might result in a significant negative impact on the flora and fauna in this part of the island.

5. Note which aspects of the proposed development pose significant concerns for plants or for wildlife and recommend measures that would mitigate or avoid these problems.

BOTANICAL SURVEY REPORT

SURVEY METHODS

A walk-through botanical survey method was used following multiple routes to ensure complete coverage of the area. Areas most likely to harbor native plants such as gullies or rock outcrops were more intensively examined. Notes were made on plant species, distribution and abundance as well as terrain and substrate.

DESCRIPTION OF THE VEGETATION

The vegetation on this property is a mixture of aggressive weedy species that have taken over since the abandonment of sugar cane agriculture, but there is also a small complement of native shrubby species scattered across the property. The most abundant plant species encountered during the survey was sourgrass (*Digitaria insularis*) which persists on overgrazed pastures because of its unpalatable nature. Also common were Guinea grass (*Panicum maximum*), Christmas berry (*Schinus terebinthifolius*), kaimi clover (*Desmodium incanum*), koa haole (*Leucaena leucocephala*), shrubby pencil flower (*Stylosanthes fruticosa*), ‘uhaloa (*Waltheria indica*), common guava (*Psidium guajava*), Java plum (*Syzygium cumini*) and lantana (*Lantana camara*).

A total of 99 plant species were recorded during the survey. Of this number 7 were native to Hawaii: ‘akia (*Wikstroemia oahuensis*), kilau (*Pteridium aquilinum var decompositum*), ‘uhaloa, ‘ulei (*Osteomeles anthyllidifolia*), pili grass (*Heteropogon contortus*), huehue (*Cocculus orbiculatus*) and pi’ipi’i (*Chrysopogon aciculatus*). None of these are rare species and all are common on multiple islands.

DISCUSSION AND RECOMMENDATIONS

The vegetation of this parcel is dominated by non-native grasses, shrubs and small trees. A few common native plant species are scattered sparsely among the non-native plants, especially in the upper parts of the property. No federally listed Threatened or Endangered plant species (USFWS, 1999) were found on the property, nor were any found that are proposed for such status. There are no special habitats here either.

Due to the lack of unique or sensitive species or habitats there is little of botanical concern with regard to this property and the proposed project is not expected to have a significant negative impact on the botanical resources in this part of O’ahu.

If, however, there is any re-vegetation planned along road cuts or on the margins of tower pads, it is suggested that some of the native species listed above be selected for propagation and outplanting.

PLANT SPECIES LIST

Following is a checklist of all those vascular plant species inventoried during the field studies. Plant families are arranged alphabetically within each of four groups: Ferns, Conifers, Monocots and Dicots. Taxonomy and nomenclature of the Conifers and of the flowering plants (Monocots and Dicots) are in accordance with Wagner et al. (1999) and Staples and Herbst, 2005). Ferns follow Palmer, (2003).

For each species, the following information is provided:

1. Scientific name with author citation

2. Common English or Hawaiian name.

3. Bio-geographical status. The following symbols are used:

   endemic = native only to the Hawaiian Islands; not naturally occurring anywhere else in the world.
   indigenous = native to the Hawaiian Islands and also to one or more other geographic area(s).
   non-native = all those plants brought to the islands intentionally or accidentally after western contact.
   Polynesia = all those plants brought to Hawaii by the Polynesians during the course of their migrations.

4. Abundance of each species within the project area:

   abundant = forming a major part of the vegetation within the project area.
   common = widely scattered throughout the area or locally abundant within a portion of it.
   uncommon = scattered sparsely throughout the area or occurring in a few small patches.
   rare = only a few isolated individuals within the project area.

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
FERNS			
DENNSTAEDTIACEAE (Bracken Fern Family)			
Pteridium aquilinum (L.) Kuhn var. decompositum (Gaud.) R.M.Tryon	kilau, bracken fern	endemic	rare
NEPHROLEPIDACEAE (Sword Fern Family)			
Nephrolepis brownii (Desv.) Hovencamp & Miyam.	Asian sword fern	non-native	uncommon
POLYPODIACEAE (Polypody Fern Family)			
Phymatosorus grossus (Langsdon&Fisch.) Brownlie	laua'e	non-native	uncommon
PTERIDACEAE (Brake Fern Family)			
Cheilanthes viridis (Forssk.) Sw.	green cliff brake	non-native	uncommon
CONIFERS			
PINACEAE (Pine Family)			
Pinus radiata D. Don	Monterey Pine	non-native	rare
MONOCOTS			
ARECACEAE (Palm Family)			
Cocos nucifera L.	coconut, niu	Polynesian	rare
Phoenix x dactylifera	hybrid date palm	non-native	rare
ASPARAGACEAE (Asparagus Family)			
Cordyline fruticosa (L.) A. Chev.	ki, ti leaf	Polynesian	rare
COMMELINACEAE (Spiderwort Family)			
Commelina diffusa N.L. Burm.	honohono	non-native	rare
CYPERACEAE (Sedge Family)			
Cyperus gracilis R. Br.	McCoy grass	non-native	rare
POACEAE (Grass Family)			
Andropogon virginicus L.	broomsedge	non-native	uncommon
Axonopus fissifolius (Raddi) Kuhlm.	narrow-leaved carpetgrass	non-native	uncommon

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Bothriochloa barbinodis (Lag.) Herter	fuzzy top	non-native	rare
Bothriochloa pertusa (L.) A. Camus	pitted beardgrass	non-native	uncommon
Chrysopogon aciculatus (Retz.) Trin.	pi'ipi'i	indigenous	uncommon
Cynodon dactylon (L.) Pers.	Bermuda grass	non-native	uncommon
Digitaria ciliaris (Retz.) Koeler	Henry's crabgrass	non-native	uncommon
Digitaria insularis (L.) Mez ex Ekman.	sourgrass	non-native	abundant
Eleusine indica (L.) Gaertn.	wiregrass	non-native	rare
Heteropogon contortus (L.) Beauv.	pili grass	indigenous	rare
Hyparrhenia rufa (Nees) Stapf	thatching grass	non-native	rare
Melinis repens (Willd.) Zizka	Natal redtop	non-native	uncommon
Panicum maximum Jacq.	Guinea grass	non-native	common
Paspalum conjugatum Bergius	Hilo grass	non-native	rare
Paspalum dilatatum Poir.	Dallis grass	non-native	uncommon
Pennisetum polystachion (L.) Schult.	feathery pennisetum	non-native	rare
Setaria parvilfora (Poir.) Kerguelen	yellow foxtail	non-native	uncommon
Sporobolus africanus (Poir.) Robyns & Tournay	African dropseed	non-native	uncommon
DICOTS			
ACANTHACEAE (Acanthus Family)			
Asystasia gangetica (L.) T.Anderson	Chinese violet	non-native	uncommon
AMARANTHACEAE (Amaranth Family)			
Acyranthes aspera L.	-------------------	non-native	rare
Amaranthus spinosus L.	spiny amaranth	non-native	rare
ANACARDIACEAE (Mango Family)			
Mangifera indica L.	mango	non-native	rare

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Schinus terebinthifolius Raddi	Christmas berry	non-native	common
APIACEAE (Parsley Family)			
Centella asiatica (L.) Urb.	Asiatic pennywort	non-native	rare
ARALIACEAE (Ginseng Family)			
Shefflera actinophylla (Endl.) Harms	octopus tree	non-native	rare
ASTERACEAE (Sunflower Family)			
Acanthospermum australe (Loefl.) Kuntze	spiny bur	non-native	uncommon
Bidens alba (L.) DC	------------------	non-native	uncommon
Conyza bonariensis (L.) Cronq.	hairy horseweed	non-native	uncommon
Elephantopus mollis Kunth	-----------------	non-native	rare
Emilia fosbergii Nicolson	red pualele	non-native	rare
Emilia sonchifolia (L.) DC.	violet pualele	non-native	rare
Pluchea carolinensis (Jacq.) G.Don	sourbush	non-native	uncommon
Pluchea indica (L.) Less.	Indian fleabane	non-native	rare
Xanthium strumarium L.	kikania	non-native	uncommon
BIGNONIACEAE (Bignonia Family)			
Spathodea campanulata P.Beauv.	African tulip tree	non-native	rare
CASUARINACEAE (She-oak Family)			
Casuarina equisetifolia Stickm.	common ironwood	non-native	rare
Casuarina glauca Sieber ex Spreng.	longleaf ironwood	non-native	rare
EUPHORBIACEAE (Spurge Family)			
Macaranga tanarius (L.) Mull. Arg.	parasol leaf tree	non-native	rare
Phyllanthus debilis Klein ex Willd.	niruri	non-native	rare
FABACEAE (Pea Family)			
Acacia confusa Merr.	Formosa koa	non-native	uncommon
Acacia farnesiana (L.) Willd.	klu	non-native	rare

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Chamaecrista nictitans (L.) Moench	partridge pea	non-native	uncommon
Crotalaria incana L.	fuzzy rattlepod	non-native	rare
Crotalaria retusa L.	rattlepod	non-native	rare
Desmanthus pernambucanus (L.) Thellung	slender mimosa	non-native	uncommon
Desmodium incanum DC.	ka'imi clover	non-native	common
Desmodium triflorum (L.) DC.	three-flowered beggarweed	non-native	rare
Indigofera suffruticosa Mill.	inikö	non-native	rare
Leucaena leucocephala (Lam.) de Wit	koa haole	non-native	common
Mimosa pudica L.	sensitive plant	non-native	uncommon
Neonotonia wightii (Wight & Arnott) Lackey	glycine	non-native	uncommon
Senna occidentalis (L.) Link	coffee senna	non-native	rare
Senna surattensis (N.L. Burm.) H. Irwin & Barneby	kolomona	non-native	uncommon
Stylosanthes fruticosa (Retz.) Alston	shrubby pencil flower	non-native	common
LAMIACEAE (Mint Family)			
Hyptis pectinata (L.) Poit.	comb hyptis	non-native	uncommon
Leonotis nepetifolia (L.) R. Br.	lion's ear	non-native	uncommon
MALVACEAE (Mallow Family)			
Abutilon grandifolium (Willd.) Sweet	hairy abutilon	non-native	uncommon
Malvastrum coromandelianum (L.) Garcke	false mallow	non-native	uncommon
Sida cordifolia L.	--------------------	non-native	rare
Sida rhombifolia L.	Cuban jute	non-native	uncommon
Sida spinosa L.	prickly sida	non-native	uncommon
Triumfetta rhomboidea Jacq.	------------------	non-native	rare
Triumfetta semitriloba Jacq.	Sacramento bur	non-native	uncommon

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Waltheria indica L.	'uhaloa	indigenous	common
MELASTOMATACEAE (Melastoma Family)			
Clidemia hirta (L.) D.Don	Koster's curse	non-native	uncommon
MENISPERMACEAE (Moonseed Family)			
Cocculus orbiculatus (L.) DC.	huehue	indigenous	uncommon
MORACEAE (Fig Family)			
Ficus platypoda (A. Cunn. ex Miq.) A. Cunn. ex Miq.	rock fig	non-native	rare
MYRSINACEAE (Myrsine Family)			
Ardisia elliptica Thunb.	shoebutton ardisia	non-native	rare
MYRTACEAE (Myrtle Family)			
Pimenta dioica (L.) Merr.	allspice	non-native	uncommon
Psidium cattleianum Sabine	strawberry guava	non-native	uncommon
Psidium guajava L.	common guava	non-native	common
Syzygium cumini (L.) Skeels	Java plum	non-native	common
OXALIDACEAE (Wood Sorrel Family)			
Oxalis corniculata L.	yellow wood sorrel	Polynesian	rare
PASSIFLORACEAE (Passion Flower Family)			
Passiflora edulis Sims	passion fruit	non-native	rare
Passiflora foetida L.	love-in-a-mist	non-native	rare
Passiflora suberosa L.	huehue haole	non-native	rare
PHYTOLACCACEAE (Pokeweed Family)			
Rivina humilis L.	rouge plant	non-native	rare
PLANTAGINACEAE (Plantain Family)			
Plantago lanceolata L.	narrow-leaved plantain	non-native	uncommon
POLYGALACEAE (Milkwort Family)			

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
Polygala paniculata L.	---------------------	non-native	rare
ROSACEAE (Rose Family)			
Osteomeles anthyllidifolia (Sm.) Lindl.	'ulei	indigneous	uncommon
RUBIACEAE (Coffee Family)			
Morinda citrifolia L.	noni	Polynesian	rare
Spermacoce assurgens Ruiz & Pav.	buttonweed	non-native	rare
SOLANACEAE (Nighshade Family)			
Capsicum frutescens L.	chili pepper	non-native	uncommon
Solanum torvum Sw.	pea aubergine	non-native	uncommon
THYMELAEACEAE ('Akia Family)			
Wikstroemia oahuensis (A. Gray) Rock	'akia	endemic	uncommon
VERBENACEAE (Verbena Family)			
Lantana camara L.	lantana	non-native	common
Stachytarpheta australis Modenke	owi	non-native	uncommon
Stachytarpheta cayennensis (Rich.) Vahl	nettle-leaved vervain	non-native	uncommon
Stachytarpheta jamaicensis (L.) Vahl	Jamaican vervain	non-native	uncommon

FAUNA SURVEY REPORT

SURVEY METHODS

A walk-through survey method was conducted in conjunction with the botanical survey. All parts of the project area were covered. Field observations were made with the aid of binoculars and by listening to vocalizations. Notes were made on species, abundance, activities and location as well as observations of trails, tracks scat and signs of feeding. In addition an evening visit was made to the area to record crepuscular activities and vocalizations and to see if there was any evidence of occurrence of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) in the area.

RESULTS

MAMMALS

Two species of mammals were observed during three site visits to the property. Taxonomy and nomenclature follow Tomich (1986).

Cattle (*Bos taurus*) – There was quite a bit of old cattle sign scattered about the property. This was from former grazing on this land.

Mongoose (*Herpestes auropunctatus*) – A few mongoose were seen scurrying through the underbrush where they hunt for rodents and birds.

Dense vegetation prevented good visibility of other small mammals. One would expect to find rats (*Rattus spp*.) and mice (*Mus domesticus*) in this type of habitat and one would expect a few feral cats (*Felis catus*) which would hunt for these rodents as well as birds.

BIRDS

Moderate birdlife diversity was observed within the project area during three site visits. Thirteen bird species were recorded including twelve non-native species and one indigenous seabird. Taxonomy and nomenclature follow American Ornithologists' Union (2005).

Red-vented bulbul (*Pycnonotus cafer*) – These dark bulbuls were abundant on all parts of this property, flying between trees and making their warbling calls.

Zebra dove (*Geopelia striata*) – These small doves were scattered throughout the property in small flocks.

Cattle egret (*Bubulcus ibis*) – A few individuals were seen during the day and small flocks were seen flying overhead heading for roosting trees during the evening.

Red-crested cardinal (*Paroaria coronata*) – A couple families of these bright red-headed birds were seen foraging in trees.

Japanese white-eye (*Zosterops japonicus*) – Several pairs of these small green birds were seen foraging for caterpillars in small trees and making their high pitched calls.

Common myna (*Acridotheres tristis*) – A few pairs of mynas were seen flying between trees throughout the property.

Northern cardinal (*Cardinalis cardinalis*) – A few of these red cardinals were seen darting about in dense forest and making their loud distinctive calls.

Red-billed leiothrix (*Leiothrix lutea*) – A few of these colorful birds were seen and heard calling from dense forest in a gully.

Spotted dove (*Streptopelia chinensis*) – Three of these large doves were seen flying between trees across the property.

Northern mockingbird (*Mimus polyglottos*) – Two mockingbirds were seen flying between trees flashing their long tail feathers.

Common waxbill (*Estrilda astrild*) – One flock of these tiny birds was seen feeding in tall grass during the late afternoon.

Red-whiskered bulbul (*Pycnonotus jocosus*) – One of these bulbuls was seen in a small tree during the late afternoon.

‘Iwa, Great frigatebird (*Fregata minor*) – One ‘iwa was seen cruising high over the property during the evening. This bird was looking for incoming seabirds he could rob of their daily catch. The ‘iwa is a widespread and common seabird throughout the tropical Pacific.

This study area is situated about ¾ mile above the substantial wetlands of the James Campbell National Wildlife Refuge that provides habitat for three Endangered Waterbirds, the ‘alae ‘ula or common moorhen (*Gallinula chloropus sandvicensis),* the ‘alae ke’oke’o or Hawaiian coot (*Fulica alai*) and the ae’o or Hawaiian stilt (*Himantopus mexicanus knudseni*) as well as other commoner waterbirds and shorebirds. These birds fly substantial distances and could overlfy the project area enroute to other wetland habitats. This area, however, has no wetland habitat to attract such waterbirds and none were seen.

INSECTS

While insects in general were not tallied, they were common throughout the property. Although not found on the property, one native sphingid moth, Blackburn's sphinx moth (*Manduca blackburni*), has been put on the Federal Endangered species list and this designation requires special focus (USFWS, 2000). Blackburn's sphinx moth was known to occur on O'ahu in the past, although it has not been found here recently. Its native host plants are species of 'aiea (*Nothocestrum spp*.) and alternative host plants are tobacco (*Nicotiana tabacum*) and tree tobacco (*Nicotiana glauca*). There are no 'aiea on or near the property, and no tobacco or tree tobacco were found on the property. No Blackburn's sphinx moth or their larvae were found.

DISCUSSION AND RECOMMENDATIONS

Most of the wildlife found on this property is non-native and is of little concern from a conservation standpoint. There are, however, wetlands in the Kahuku area that provide habitat for Endangered waterbirds, and the Endangered Hawaiian hoary bat has been detected about a mile to the southeast in a recent survey. The presence of these Endangered volant birds and bat in the general vicinity of proposed wind turbines raises concerns for their safety that may need to be addressed proactively in consultation with the U.S. Fish and Wildlife Service which exercises jurisdiction over these animals under the authority of the Endangered Species Act.

No other concerns regarding the wildlife of this project area are anticipated and no further recommendations are offered.

ANIMAL SPECIES LIST

Following is a checklist of the animal species inventoried during the field work. Animal species are arranged in descending abundance within two groups: Mammals and Birds. For each species the following information is provided:

1. Common name

2. Scientific name

3. Bio-geographical status. The following symbols are used:

   endemic = native only to Hawaii; not naturally occurring anywhere else in the world.
   indigenous = native to the Hawaiian Islands and also to one or more other geographic area(s).
   non-native = all those animals brought to Hawaii intentionally or accidentally after western contact.
   migratory = spending a portion of the year in Hawaii and a portion elsewhere. In Hawaii the migratory birds are usually in the overwintering/non-breeding phase of their life cycle.

4. Abundance of each species within the project area:

   abundant = many flocks or individuals seen throughout the area at all times of day.
   common = a few flocks or well scattered individuals throughout the area.
   uncommon = only one flock or several individuals seen within the project area.
   rare = only one or two seen within the project area.

COMMON NAME	SCIENTIFIC NAME	STATUS	ABUNDANCE
MAMMALS			
Cattle	*Bos taurus*	non-native	uncommon
Mongoose	*Herpestes auropunctatus*	non-native	uncommon
BIRDS			
Red-vented bulbul	*Pycnonotus cafer*	non-native	abundant
Zebra dove	*Geopelia striata*	non-native	uncommon
Cattle egret	*Bubulcus ibis*	non-native	uncommon
Red-crested cardinal	*Paroaria coronata*	non-native	uncommon
Japanese white-eye	*Zosterops japonicus*	non-native	uncommon
Common myna	*Acridotheres tristis*	non-native	uncommon
Northern cardinal	*Cardinalis cardinalis*	non-native	uncommon
Red-billed leiothrix	*Leiothrix lutea*	non-native	uncommon
Spotted dove	*Streptopelia chinensis*	non-native	uncommon
Northern mockingbird	*Mimus polyglottos*	non-native	rare
Common waxbill	*Estrilda astrild*	non-native	rare
Red-whiskered bulbul	*Pycnonotus jocosus*	non-native	rare
'Iwa, Great frigatebird	*Fregata minor palmerstoni*	indigenous	rare

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Appendix 11

Hamakua Marsh Waterbird Management Plan for Kahuku Wind Power Habitat Conservation Plan (Implemented Under the Baseline Scenario for Waterbird Mitigation)

February 2010

Background

Hamakua Marsh State Wildlife Sanctuary is a 22-ac. (8.9-ha) state-owned and managed wetland located on the windward side of Oahu (Figure 1). The marsh is characterized as a seasonal floodplain and is divided into four basins, approximately two to eight acres (0.8 – 3.2 ha) in size. These basins are fed by runoff from the Puʻu o ʻEhu hillside adjacent to the wetland. The Hamakua canal that borders three of the four basins also contributes to flooding of the wetland during the rainy season and times of high tidal influx.

The Hamakua Marsh Wildlife Sanctuary has been managed by the State of Hawaiʻi Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) since 1995 for the four federally endangered waterbird species/sub-species present in Hawaiʻi: the Hawaiian duck (*Anas wyvilliana*), Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), and Hawaiian moorhen (*Gallinula chloropus sandvicensis*). All four waterbird species have been documented nesting in the area.[1]

Under the Hamakua Marsh Ecosystem Restoration and Community Development Project initiated in 2001, management activities conducted at Hamakua Marsh have included the removal of red mangrove (*Rhizophora mangle*) from the banks of the marsh, the outplanting of native species within the marsh, and the provision of adequate nesting habitat for the marsh's endangered waterbird species. Waterbird nesting activity and habitat utilization were measured at Hamakua Marsh in 2003 and 2004 to document the response of waterbirds to these management activities (Smith and Polhemus 2003, Polhemus and Smith 2005). Since then, DOFAW has conducted weekly surveys during the waterbird nesting season (from December to August) to document waterbird nesting success; these on-going surveys occur on a yearly basis. Many of the waterbirds at the Hamakua Marsh Wildlife Sanctuary have also been banded to document their survival and dispersal.

Two main management activities currently occur at Hamakua Marsh State Wildlife Sanctuary – predator control (first started 2003) and vegetation maintenance on an as needed basis. The level of effort for each activity has been contingent upon the availability of funding and has varied over the past seven years.

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[1] All Hawaiian ducks occurring at Hamakua Marsh State Wildlife Sanctuary and elsewhere on Oʻahu are believed to actually be Hawaiian duck x mallard (*Anas platyrhynchos*) duck hybrids.

Map Document: (G:\Projects\14000\14492_Kahuku_Wind\MXD\Waterbird Management Plan\Figure 1 - Hamakua Marsh.mxd) 12/11/2009 -- 12:07:11 PM

Legend

- Hamakua Marsh Parcel Boundary
- Wetlands
- TMK Parcels

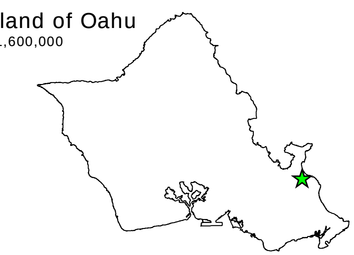
Figure 1
Hamakua Marsh

N

500 250 0 500
Feet

200 100 0 200
Meters

Island of Oahu
1:1,600,000



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CLEAN ENERGY. MADE HERE.

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ENVIRONMENTAL CONSULTANTS

Sources:
Base Data - State of Hawaii GIS
Wetlands - U.S. Fish and Wildlife Service, September 25, 2009
Aerial Photo - USDA-FSA-APFO, Oahu Digital Orthophoto Mosaic

Kahuku Wind Power plans to construct and operate a new 30-megawatt (MW), 12-turbine commercial wind energy generation facility in the Kahuku area on the northeastern portion of O‘ahu (SWCA 2009). Operation of the project may result in the incidental take of individuals of the four above-mentioned endangered waterbird species. Therefore, Kahuku Wind Power is seeking an Incidental Take License (ITL) in accordance with Chapter 195-D, Hawai‘i Revised Statutes and has prepared a Habitat Conservation Plan (HCP) in support of the license that prescribes methods to avoid, reduce, and mitigate for incidental take of affected endangered species. Through consultation with the U.S. Fish and Wildlife Service (USFWS) and DOFAW, Hamakua Marsh State Wildlife Sanctuary was identified as a suitable site for Kahuku Wind Power to implement mitigation measures for the covered waterbird species under the HCP. Funding will be provided by Kahuku Wind Power to a qualified contractor or personnel approved by DLNR and USFWS, which will implement the mitigation measures as stipulated in this management plan. The successful implementation of this management plan requires the fulfillment of the obligations identified below.

1) Identification of suitable management and monitoring measures to compensate for take that is measured or anticipated to occur at Kahuku Wind Power. Stipulations require that:
    a. Any measures funded by Kahuku Wind Power are above and beyond any measures currently being implemented. Kahuku Wind Power may also fund on-going measures if it is demonstrated that these measures will not be implemented otherwise;
    b. The success of any management measure implemented must be quantifiable (e.g., result in a measurable increase in productivity or survival rates of chicks or adults); and
    c. Management measures must aid in species recovery and provide a net conservation benefit.
2) Timely execution of the management measures as agreed upon by the vendor;
3) Documentation and quantification of the success of the management measures through monitoring of efforts which in turn require:
    a. An adequate baseline of reproductive activity to which the success of management measures can be compared; and
    b. Consistent monitoring of the predator control effort and waterbird productivity to document the progress of the management and identification of new or emerging threats to the waterbird species should they arise.
4) Yearly reporting on the success of the management measures which will include:
    a. Quantification of the success of management measures using a baseline; and
    b. Recommendations for the continued implementation of measures or improvements/changes to those measures to increase success as documented through the monitoring process.

1. Management Measures and Monitoring

Discussions with DOFAW biologists have identified predator control and vegetation maintenance as key needs for maintaining and increasing waterbird productivity at Hamakua Marsh. DOFAW funded predator control has been conducted via contract with the U.S. Department of Agriculture Animal and Plant Health Inspection Service, Wildlife Services (Wildlife Services) since 2007. Due to budget constraints, DOFAW has indicated that as of 2010 funding will no longer be available to continue the predator control measures at Hamakua Marsh. Funding for continued vegetation maintenance is also necessary to maintain and increase available nesting habitat for waterbirds at Hamakua Marsh.

Based on the needs identified by DOFAW biologists and with the concurrence of USFWS, the following management actions will be funded by Kahuku Wind Power. Each action will be funded for a minimum of three years and maximum of five years. All permits and approvals required to implement the Hamakua Marsh Waterbird Management Plan have already been secured by DOFAW. The proposed budget is presented in Appendix A.

Predator Control and Monitoring of Effort. These actions will be conducted year round by Wildlife Services, or other qualified contractors or personnel approved by DLNR and USFWS. Predator control will consist of deploying live traps, leg-hold traps, and/or snares targeted at dogs, feral and free-ranging cats, mongoose and rats. Bait stations will also be used to control rats and mongoose. Hunting will be conducted during the non-breeding season for stilt. Trapping, baiting and hunting will be done according to methodology that has been used at Hamakua Marsh since predator control by Wildlife Services began in 2007. The methods are described below.

- **Live Traps.** Live traps will be placed along the access road on the southern edge of the marsh. These traps will be spaced 160 to 200 ft (50- 60 m) apart (Misaki pers. comm.).

- **Leg-hold Traps and Snares.** These types of traps will be placed deeper within the marsh, depending on visual observations of predators. Leg hold traps and snares will be used when predator signs (tracks, scat, etc.) are observed in the marsh in conjunction with the use of live traps. Both feral pigs and dogs have been observed in the ranch lands bordering the marsh.

- **Bait Stations.** Bait stations to control rodents and mongoose will be placed at a density of four bait stations per acre (USDA 2009). Bait stations will be deployed year-round following protocols set forth by the Department of Agriculture (DOA).

- **Hunting.** Hunting will only be conducted during the non-breeding season for stilt (USDA 2009). The vendor will consult with DOFAW before any hunting activities begin. Predators that cannot be trapped or snared will be targeted and may include dogs, cats, pigs, feral ducks (e.g. “green-head” mallards and Muscovies)[2] and geese.

- **Monitoring of Traps and Bait Stations.** Live traps will be checked every 48 hours and leg-hold traps and snares will be checked every 24 hours in accordance with USFWS guidelines to minimize potential for accidental take of Hawaiian moorhens and other waterbirds (USDA 2009). Bait stations will be checked and replenished as necessary and bait take documented. All label restrictions and guidelines will be followed.

- **Release of Non-targeted Animals.** Any non-targeted animals (listed species, native species, or otherwise) captured in traps will be released alive if found unharmed. Injured wildlife will be promptly delivered to a licensed wildlife rehabilitator. All federally listed species will be taken to a wildlife rehabilitator with appropriate federal and state permits. Licensed wildlife rehabilitators occurring in the general vicinity of Hamakua Marsh Wildlife Sanctuary are identified in Appendix B. Kahuku Wind Power will be responsible for reimbursement for all costs and measures (veterinary and/or rehabilitative care, release, etc.) related to ‘by-catch’ of non-target (listed and federally protected) individuals assuming all efforts are made to prevent such unintended consequences. If any federally protected species are captured, notification and reporting procedures according to the ITL shall be followed.

- **Disposal.** All captured predators will be properly euthanized in the field by Wildlife Services and taken off site for disposal at an appropriate facility.

Tracking Tunnels. Tracking tunnels will be deployed once a month along established traplines and deeper within the marsh to provide an index of predator activity. Deployment and monitoring of tracking tunnels will be conducted by qualified contractors or personnel approved by DLNR and USFWS. Tracking tunnels will be deployed for the duration of the predator control effort and evaluated as needed by DOFAW and USFWS. These tunnels will be large enough to be capable of recording the presence of rats and mongoose, but will not be large enough to record dogs or cats. Tunnels will be deployed for one tracking tunnel night per month at a density of 1 per hectare and spaced no closer than 50 m from each other (Gillies and Williams 2009). It is recommended that two tracking tunnels be placed on each dike (Figure 1), as these are likely to be the main access points for rats and mongoose into the marsh. The index of activity (percent tunnels with activity) will provide information on the success of the predator control methods in reducing predator densities, identify areas that may need increased trapping effort, and identify seasonal changes in occurrence and abundance of predators if any.

[2] As soon as a Hawaiian duck/mallard key is approved feral mallard control will be increased

- **Reporting for Predator Control and Tracking Tunnels.** Quarterly reports will be provided by the vendor to Kahuku Wind Power (see Appendix C). Each report will summarize for each month
    - the number of hours spent on trapping and baiting;
    - the number of hours spent on track tunnel deployment;
    - number of traps and bait stations deployed;
    - the number of predators trapped;
    - the amount of bait taken; and
    - tracking tunnel index of activity

  Each report will also identify whether any non-targeted species were captured for each month and their final disposition. Reports will be submitted to Kahuku Wind Power within 21 days of the end of each quarter.

Vegetation Management. Vegetation management will be conducted by qualified contractors or personnel approved by DLNR and USFWS.

- **Vegetation Maintenance.** Management of vegetation at Hamakua Marsh will be done throughout the year using herbicides, machinery, and hand tools. Native outplantings will be established to re-vegetate cleared areas and to reduce the need for vegetation maintenance. Kou (*Cordia subcordata*), milo (*Thespesia populnea*)[3], naio (*Myoporum sandwicense*), ʻahuʻawa (*Cyperus javanicus*), and other common native marsh plants will be established where invasive grasses have been removed. Non-native Guinea grass (*Urochloa maxima*) and California grass (*Urochloa mutica*) will be targeted for removal so as to reduce biomass and encourage growth of native plants and the non-native Bermuda grass (*Cynodon* spp.). Bermuda grass populations will be encouraged on access roads, outplanting sites and slopes to reduce erosion and maintenance on Guinea grass and California grass. Indian fleabane (*Pluchea indica*) and koa haole (*Leucaena leucocephala*) are less common in the area and will be controlled using power tools and herbicides.

  Pickleweed (*Batis maritime*) will be controlled in the inner portions of the basins, where water is present most of the year, using heavy machinery (tractor/Bobcat) with a rotary tiller attachment. The rotary tiller will break-up the pickleweed and reduces the time for re-sprouts to occur. The pickleweed will be tilled after all stilt nesting activity is completed, as indicated by the survey of nesting activities done by the field biologist. This generally occurs during the late summer months and early

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[3] *Thespesia populnea* is probably indigenous to Hawai'i, most likely having been introduced by the early Polynesians

fall when the basins are relatively dry. Open mudflats are the result of the tilling, and are ideal feeding habitat for Hawaiian stilts. Although the pickleweed is a non-native species, it does provide benefits to waterbirds, if controlled on a yearly basis. Replacing the pickleweed with native sedges would be most effective, but is a less feasible alternative as native sedges have not responded well to date. After tilling, the pickleweed grows back sporadically, creating broken patches of vegetation which provide ideal cover for newly hatched chicks. Pickleweed along the canal is utilized by the Hawaiian moorhens and Hawaiian coots for nesting, loafing and feeding.

• **Reporting.** Quarterly reports on vegetation management activities and any vegetation management needs will be provided by the vendor to Kahuku Wind Power (Appendix C). Reports will be submitted within 21 days of the end of each quarter and will include the number hours spent of vegetation maintenance, a brief summary of vegetation maintenance activities and photo monitoring points and/or sketches of the habitat (Appendix C).

- **Monitoring of Nesting Activity and Reproductive Success of Waterbirds.** Weekly surveys of waterbird nesting activity, and chick survival and fledgling success will be conducted by qualified contractors or personnel approved by DLNR and USFWS. Surveys will run from December to September each year, or until the outcome of the last observed nesting attempt is known. Information will be collected for all listed waterbird species present and will include:

    - Hours spent on waterbird monitoring;
    - Number of pairs with territories;
    - Sketch map of pair territories and nest locations;
    - Location of nests visible from survey route
    - Number of eggs per nest as visible;
    - Number of chicks per pair/territory;
    - Number of fledglings produced per pair (nest success);
    - Band resighting of any banded birds; and
    - Any evidence of predation, including identification of specific predators if possible

These data will enable Kahuku Wind Power to determine productivity and nesting success of the waterbirds at the Hamakua Marsh resulting from the implementation of the HCP management measures.

In addition to the information documented, as far as practicable, chicks or fledglings of the waterbird species will be banded annually to track the survival of individuals and enable a record of waterbird movement between wetlands. Currently, stilts and moorhens at Hamakua Marsh are banded annually.

- **Reporting.** The vendor will submit a report on waterbird reproductive activity at Hamakua Marsh to Kahuku Wind Power by September 30 of each year (Appendix C). In addition to providing the above listed data, the report shall contain the following information:
  - Species and number of birds banded
  - Likely factors affecting nesting success (e.g. identification of numbers of nests/species, numbers of eggs/nest, hatching success of eggs, chick or fledgling success and any predator interactions);
  - Likely factors affecting adult survival if any; and
  - Recommendations to continue current trapping and monitoring efforts or recommended modifications to management measures

2. Development of Baseline

Reproductive success of the four federally and state listed waterbird species has been documented at Hamakua Marsh Wildlife Sanctuary since 2003. Surveys in 2003 and 2004 (Table 1. Smith and Polhemus 2003, Polhemus and Smith 2005) documented hatchling numbers but the monitoring period did not extend through the fledging phase. Systematic waterbird surveys by DOFAW in 2005 documented chick survival through the fledgling period for the various management measures implemented (Table 2).

Since 2005, management efforts at Hamakua marsh have gradually increased. Data from past DOFAW surveys have been used to develop a baseline for the management efforts proposed in this document. A baseline for waterbird productivity at Hamakua Marsh would be waterbird productivity in the absence of predator control or vegetation management. In discussions with DOFAW and USFWS biologists, it was determined that in the absence of any management, it is likely that it will take several years for the marsh to return to its previously unmanaged state. Therefore, in order to account for the habitat improvements achieved thus far, the baseline for the near-term (i.e. within the next 3-5 years) was set as the average number of fledglings produced between years 2005-2009 (Table 2).

This baseline may be adjusted in the future as necessary, as biological data or other information become available to improve the methods of determining a baseline. Adjustments to the baseline will be made with the concurrence of Kahuku Wind Power, USFWS, and DOFAW.

Table 1. Hamakua Marsh Waterbird Reproductive Activity 2003-2004

Year	Species (total chicks observed)			Vegetation Maintenance	Predator control
	Coot	Moorhen	Stilt		
2003[1]	Not monitored	44	18	Vegetation removal	Year-round bait stations, trapping during breeding season
2004[2]	2	36	21	Vegetation maintenance, tilling	Not available

[1] Smith and Polhemus (2003) [2] Polhemus and Smith (2005)

Table 2. Hamakua Marsh Waterbird Reproductive Activity 2005-2009 from DOFAW

Year	Species (total fledglings observed)			Measures	
	Coot	Moorhen	Stilt	Vegetation Maintenance	Predator control
Pre 2003*	Not monitored	Not monitored	3	None	None
2005	1	13	1	Grass management, limited tilling	predator control during nesting season
2006	0	51	15	Tilling post breeding 2005	Predator control during nesting season
2007	1	36	13	No tilling	Predator control year round
2008	5	33	10	No tilling	Predator control year round
2009	5	52	16	Increased vegetation maintenance, tilling post 2008 breeding season	Predator control year round
Average for 2005-2009	**2.2**	**36.6**	**11**		

*information from Smith and Polhemus (2003)

Baseline

3. Determination of the Effectiveness of Management Measures

Kahuku Wind Power, DLNR, and USFWS will evaluate the success of management measures annually upon receipt of that year's report on waterbird reproductive success from the vendor, and the final reports for the year on the results of vegetation maintenance and predator control. Success will be determined by comparing each year's reproductive success against the identified baseline level. Success for each listed waterbird species will be quantified by the difference in number of fledglings produced over baseline level. Barring unusual circumstances (e.g. excessive flooding, disease outbreaks) the number of fledglings produced should exceed the baseline. Management efforts will be deemed to have been successful if Kahuku Wind Power produces greater than one fledgling of the required mitigation (essentially the Baseline requested take, see HCP section 6.3.4 and 7.4) for each listed waterbird species after completion of the three to five years of management proposed in this plan. As long as management activities are executed by the vendor on a timely basis as agreed upon, Kahuku Wind Power will be solely responsible for meeting the success criteria outlined above. Management measures may be extended for up to another 5 years to meet the success criteria and implemented with additional funding.

Should at any time, Kahuku Wind Power, DLNR and USFWS determine that management measures will not be within one fledgling of their mitigation requirements or the fledglings produced per year are lower than the baseline, adjustments to management measures may be implemented as discussed in Section 4.

4. Adjustments to Management Measures

Management measures may be modified to increase the effectiveness of the management efforts outlined in this plan. Kahuku Wind Power may call a meeting at any time to discuss changes in management measures based on feedback from vendors, Wildlife Services, DOFAW biologists, USFWS biologists, Kahuku Wind Power staff, new information or technology, or improvements to trapping and monitoring techniques. Changes in management measures will be made with the concurrence of DLNR, USFWS and Kahuku Wind Power. All changes will be performed under the existing budget for this management plan.

Management measures may also be improved using data gathered from predator control efforts, tracking tunnel monitoring, and monitoring of waterbird reproductive success. If enough data is collected, a population viability analysis may be conducted to identify key life stages or ecological processes to focus on and may also be used to compare different management options. Possible adjustments are outlined below.

<u>Predator Control Efforts and Track Tunnel Monitoring</u>

Predator control efforts are constant year round, should track tunnel monitoring show:

a) consistently high predator activity year-round

a. Predator control efforts will be increased year-round by deploying traps/bait more often, as far as practicable, increasing the density of traps/bait in the area, or methods will be added to target specific predator groups

b. Predator control efforts will be increased until tracking tunnels show a drop in predator activity from existing levels. Multiple predator control methods may also be employed if the rate of ingress, especially from rats from adjacent urban areas, is so great that the currently employed control method cannot decrease predator activity in the area.

b) an increase in predator activity for certain months of the year indicating a seasonal increase in predators

a. Predator control efforts will be increased during those months by deploying traps/bait more often or increasing the density of traps/bait in the area

b. Predator control efforts will be increased until tracking tunnels show a drop in predator activity from previously measured levels

c. Specific predators (i.e. rats or mongoose) may be targeted if tracking tunnels show an increase in only certain groups of predators

c) an increase in predator activity for certain portions of the site

a. Predator control efforts will be increased in those areas by deploying traps/bait more often or increasing the density of traps/bait in the area

b. Predator control efforts will be increased till tracking tunnels show a drop in predator activity from previously measured levels

c. Specific predators (i.e. rats or mongoose) may be targeted if tracking tunnels show an increase in only certain groups of predators

d) trap success declines and predator activity increases

a. Trap type or bait type may be changed or alternative methods to target these groups of predators will be employed

<u>Waterbird Monitoring</u>

Should waterbird monitoring show:

a) fledgling success of waterbirds has not increased over baseline levels and that predators are still a main cause of mortality

a. Predator control efforts will be increased year-round by deploying traps/bait more often or increasing the density of traps/bait in the area

b. Predator control efforts will be increased until tracking tunnels show a drop in predator activity

b) that productivity is suppressed due to loss of young at specific life stages (e.g. egg stage, chick stage) caused by specific groups of predators

   a. Predator control efforts will be modified by increasing trapping effort or using trapping methods targeted at specific groups of predators

c) that other factors are contributing to a substantial loss of productivity

   a. Methods to mitigate for these factors may be employed in addition to the ongoing management measures in effect

5. List of Preparers

This document was prepared by L. Ong, P. Sunby and S. Mosher of SWCA Environmental Consultants, J. Misaki and N. Bustos from DOFAW and J. Kwon from USFWS. Input from A. Nadig from USFWS, S. Fretz, and L. Goodmiller from DOFAW and M. Ono from Wildlife Services is gratefully acknowledged.

References:

Gillies, C. and Williams D. 2009. Using tracking tunnels to monitor rodents and mustelids. Draft Report.

Polhemus, J.T. and D.G. Smith. 2005. Update on Nesting Activity and Habitat Utilization by Native Waterbirds at the Hamakua Marsh State Wildlife Sanctuary, Kailua, O‘ahu. Elepaio 65(3):17-21

Smith D.G., J.T. Polhemus. 2003 Habitat Use and Nesting Activity by the Hawaiian Stilt (*Himanotopus mexicanus knudseni*) and Hawaiian Moorhen (*Gallinula chloropus sandvicensis*) at the Hamakua Marsh State Wildlife Sanctuary, Kailua, O‘ahu. ‘Elepaio 63(8):59-62

SWCA 2009. Draft Habitat Conservation Plan for Kahuku Wind Power.Available at http://hawaii.gov/dlnr/dofaw/pubs/2009/KahukHCP_BLNR.pdf/view.

United States Department of Agriculture (USDA). 2009. Environmental Assessment: Predator Damage Management to Protect Avian Wildlife in Hawaii.

Appendix A Proposed Budget

Personnel	Responsibilities	Cost per year
Wildlife Services or other vendor	Year-round predator control, tracking tunnel monitoring, reporting to DOFAW and Kahuku Wind Power	$27,000
Wildlife Biologist (full time)	Survey and inventory of waterbirds, facilitation and coordination of predator control efforts, vegetation maintenance, purchasing rodenticide, maintenance of machinery and vehicle, and outreach. Compiling of reports and information to Kahuku Wind Power	$65,500
	Total per year	**$92,500**
Equipment	Truck and monitoring equipment	$14,000
	3-year total	**$291,000**

Appendix B State and Federally Permitted Wildlife Rehabilitators

Aloha Animal Hospital
Dr. Doug Chang, DVM
4224 Waialae Avenue
Honolulu, HI 96816
Phone: (808)734-2242
Rehabilitates: Native, Endangered, and Migratory species only

Carolyn Blackburn
4106 Blackpoint Road
Honolulu, HI 96816
Phone (808) 739-2023
Rehabilitates: Native species

Appendix C Checklist of Deliverables From Vendors

Trapping and Tracking Tunnels (quarterly reports)

Reports will be submitted within 21 days of the end of each quarter to Kahuku Wind Power and will include the following items for each month:

- Hours spent on predator trapping and baiting;
- Hours spent on track tunnel deployment;
- Number of traps and bait stations deployed;
- Number of predators trapped;
- Amount of bait taken;
- Tracking tunnel index of activity (percent activity by predator type i.e. mongoose or rat); and
- Whether any non-targeted species were captured for each month and their final disposition

Vegetation Maintenance (quarterly reports)

Reports will be submitted within 21 days of the end of each quarter to Kahuku Wind Power and will include the following items

- Hours spent on vegetation maintenance;
- Brief summary of vegetation maintenance activites; and
- Photo monitoring points and/or sketches of the habitat

Waterbird productivity (annual report)

The vendor will submit a report on waterbird reproductive activity at Hamakua Marsh to Kahuku Wind Power by September 30 of each year and will include the following items

- Hours spent on monitoring;
- Number of pairs with territories;
- Sketch map of pair territories and nest locations;
- Location of nests visible from survey route;
- Number of eggs per nest as visible;
- Number of chicks per pair/territory;
- Number of fledglings produced per pair (nest success);
- Any evidence of predation, including identification of specific predators if possible.
- Number and species of birds banded;
- Likely factors affecting nest success (e.g. identification of egg, chick or fledgling predators);
- Likely factors affecting adult survival if any; and
- Recommendations to continue current trapping and monitoring efforts or recommended modifications to management measures

Appendix 12

List of Plant Species Observed at Flying R Ranch

The following checklist is an inventory of all the plant species observed by SWCA biologists on December 16, 2009 at the Flying R Ranch site, Island of Oʻahu. SWCA staff conducted a walk-through survey method of an approximate 50 x 40 m (164 x 131 ft) area surrounding the proposed microwave tower site and along the dirt trail leading to the site. All plant species were documented and notes were made on plant communities, relative abundances, and substrate types. Plant identifications were made in the field; however, plants which could not be positively identified were collected for later determination in the herbarium, and for comparison with the most recent taxonomic literature.

The plant names are arranged alphabetically by family and then by species into each of two groups: Monocots and Dicots. The taxonomy and nomenclature of the flowering plants are in accordance with Wagner et al. (1990, 1999), Wagner and Herbst (1999), and Staples and Herbst (2005). Recent name changes are those recorded in the Hawaii Biological Survey series (Evenhuis and Eldredge, eds., 1999-2002).

For each species, the following is provided:

1. Scientific name with author citation.

2. Common English and/or Hawaiian name(s), when known.

3. Biogeographic status. The following symbols are used:

    - E= endemic= native only to the Hawaiian Islands.
    - I= indigenous= native to the Hawaiian Islands and elsewhere.
    - P = introduced by Polynesians.
    - X=introduced or alien = all those plants brought to the Hawaiian Islands by humans, intentionally or accidentally, after Western contact (Cook's arrival in the islands in 1778).

4. Relative site abundance. The following categories are used.

    - Abundant = forming a major part of the vegetation within the survey area.
    - Common = widely scattered throughout the area or locally abundant within a portion of it.
    - Uncommon = scattered sparsely throughout the area or occurring in a few small patches.
    - Rare = only a few isolated individuals within the survey area.

SCIENTIFIC NAME	COMMON NAME	STATUS	ABUNDANCE
ANGIOSPERMS- MONOCOTS			
POACEAE			
Melinis repens (Willd.) Zizka	natal red top	X	Rare
Urochloa maxima (Jacq.) R. Webster	Guinea grass	X	Common
ANGIOSPERMS- DICOTS			
ANACARDIACEAE			
Schinus terebinthifolius Raddi	Christmas berry	X	Rare
ASTERACEAE			
Ageratum conyzoides L.	maile honohono	X	Common
EUPHORBIACEAE			
Phyllanthus debilis Klein ex Willd.	niruri	X	Rare
FABACEAE			
Acacia farnesiana (L.) Willd.	klu, aroma, kolu	X	Rare
Desmodium incanum DC.	Spanish clover, ka'imi	X	Uncommon
Mimosa pudica L.	sensitive plant, sleeping grass	X	Uncommon
Senna surattensis (Burm.f.) H.S.Irwin & Barneby	Kolomona, scrambled egg plant	X	Rare
Stylosanthes sp.	---	X	Rare
MALVACEAE			
Sida acuta N.L. Burm.	---	X	Uncommon
Sida rhombifolia L.	---	X	Uncommon
MYRTACEAE			
Syzygium cumini (L.) Skeels	Java plum	X	Common
OXALIDACEAE			
Oxalis corniculata L.	yellow wood sorrel, 'ihi 'ai	X	Rare
PROTEACEAE			
Grevillea robusta A.Cunn. ex R.Br.	silver oak, silk oak	X	Rare
SAPINDACEAE			
Dodonaea viscosa Jacq.	a'ali'i	I	Rare
STERCULIACEAE			
Waltheria indica L.	'uhaloa	I	Uncommon
VERBANACEAE			
Stachytarpheta jamaicensis (L.) Vahl	Jamaica vervain	X	Common

Appendix 13

Downed Wildlife Protocol

Kahuku Wind Power
Habitat Conservation Plan

Purpose:	To identify and document any wildlife injury or fatality incident that involves Covered and MBTA Species at the Kahuku Wind Power site incidental to and during regular monitoring.
Applicability:	This protocol applies to all employees of Kahuku Wind Power and its affiliates, and extends to all consultants, contractors, or other personnel who work on the site.
Covered Species:	Covered Species include the federally *endangered* Hawaiian Petrel, Hawaiian Stilt, Hawaiian Moorhen, Hawaiian Coot, Hawaiian Duck or hybrids, Hawaiian Hoary Bat, state *endangered* Hawaiian short-eared owl, and the federally *threatened* Newell's Shearwater. MBTA species include all species covered under the provisions of the federal Migratory Bird Treaty Act.
Overall Approach:	Downed wildlife may be located during the course of regular monitoring or opportunistically during routine site work. In addition to the project's monitoring program, which is a component of the project's Habitat Conservation Plan, project consultants and personnel will routinely look for and exhibit awareness of the potential to encounter downed wildlife when working at individual turbine sites, when traveling along site roads by vehicle, and when traveling the site on foot. Should any downed wildlife be found or reported, the responsible party (Senior Wildlife Biologist, Site Compliance Officer, or their official designee) shall contact Oahu DLNR Forestry and Wildlife Division immediately to initiate response coordination: (Oahu Wildlife Program Manager) at 808-973-9786, 808-295-5896. A written report that provides documentation and details of the incident will be submitted to DLNR/DOFAW and USFWS within 5 business days following the incident. All downed wildlife will be left in place until agency personnel arrive or unless directed by USFWS or DLNR personnel. Injured wildlife may require, if instructed directly by DLNR or USFWS, that the responsible party transport the downed individual in an appropriate container (e.g. ventilated pet carrier) either to a qualified veterinarian or other facility specified by DLNR or USFWS, as described below, as soon as possible and appropriate (e.g., if the individual is alive, it shall be transported immediately). The responsible party will also complete a Downed Wildlife Monitoring Form and an official Incident Report will be submitted to DLNR and USFWS within 5 business days following the incident.
Facility Information:	TBD Phone:
Kahuku Wind Power Contact Information:	Gregory Spencer, Senior Wildlife Biologist Phone: (808) 298-5097

Kahuku Wind Power, LLC

Habitat Conservation Plan
Downed Wildlife Incident Documentation and Reporting Form

Observer Name	
Date	
Species (common name)	
Time Observed (HST)	
Time Initially Reported (HST)	
Time Responders Arrive (HST)	
Location	
GPS Coordinates (specify units and datum)	
Date Last Surveyed	
Distance to Base of nearest WTG (m)	
Bearing from Base of nearest WTG	
Ground Cover Type	
Wind Direction and Speed (mph)	
Cloud Cover (%)	
Cloud Deck (magl)	
Precipitation	
Temperature (^{o}F)	

Condition of Specimen:
Probable Cause of Injuries and Supportive Evidence:
Action Taken:

Appendix 14

Makamaka'ole Seabird Mitigation and Management Plan (with KWP and KWP II)

Calendar Year	Task/Item	By	Estimated Cost ($1,000s)	Project Share		
				KWP	KWP II	Kahuku
2010	• Site reconnaissance and avian activity observations • Preliminary fence location and layout with DLNR and USFWS • Possible preliminary social attraction/burrow installations • Site investigations by botanist and cultural expert • Prepare feasibility assessment by September 1, 2010 • Reach decision on feasibility with agencies • If project is feasible, prepare EA and file permit applications	Project Staff/ Consultant	100	75		25
2011	• Permit application review and processing • Solicit bids/select contractor • Follow-up reconnaissance/construction planning	Project Staff/ Consultant	100		75	25
	• Begin construction of approx. 2 miles of fence in late 2011	Contractor	250	75	100	75
2012	• Complete fence construction	Contractor	250	75	100	75
	• Intensive predator trapping/bait boxes • Social attraction and artificial burrows • Monitoring	Project Staff/ Interns	100	25	50	25
2013	• Mop-up predator trapping • Continue bait boxes • Social attraction and artificial burrows • Monitoring	Project Staff/ Interns	75	25	25	25
2014	• Inspections (fence/predator) • Bait boxes • Social attraction and artificial burrows • Monitoring	Project Staff/ Interns	75	25	25	25
2015	• Inspections (fence/predator) • Bait boxes • Social attraction and artificial burrows • Monitoring	Project Staff/ Interns	75	25	25	25
2016-2030	• Social attraction continues in 2016 • Inspections (fence/predator) • Bait boxes • $25,000/yr for 15 years	Project Staff/ Interns	375	75	150	150
		Totals	**1400**	**400**	**550**	**450**